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ABSTRACT

Foundational Approaches in Science Teaching (FAST) is a program which is intended to facilitate student transition from the general science process programs of elementary schools to the discipline-oriented programs of high school. This guide has been developed to provide an overview of the total program as well as a description of the instructional materials and strategies. The information in the document: (1) explains the assumptions, goals, and objectives of the FAST program; (2) describes the content of the three FAST levels (the local environment--FAST 1; flow of matter and energy in the biosphere--FAST 2; and change over time--FAST 3); (3) outlines alternative time schedules and sequences of student investigations; (4) identifies teacher and student materials and their use; and (5) suggests general strategies for classroom organizations and management. Particular attention is given to guidelines for planning and conducting effective group interactions for problem solving situations. (TW)

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Instructional Guide

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FAST

Foundational Approaches in Science Teaching
Curriculum Research and Development Group

SE 047 514

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PREFACE

The Foundational Approaches in Science Teaching (FAST) program is designed to involve both teachers and students in the activities of science. In the day-to-day activities in the classroom, it is often easy to lose sight of the overall objectives, structure, function, and sequence of a program. This FAST Instructional Guide has been developed to give an overview of the total program as well as a detailed description of the material and instructional strategies. The guide has been written out of the practical experience of classroom observations and teacher and administrator feedback. The information in the Instructional Guide

1. describes the assumptions, goals, and objectives of the FAST program.
2. describes the content of the three levels of the FAST program.
3. outlines alternative time schedules and sequences of student investigations.
4. describes teacher and student materials and their use.
5. suggests general strategies for classroom organization and management.

We hope that this guide proves helpful in carrying out the program in schools.

Donald B. Young
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I. FOUNDATIONAL APPROACHES IN SCIENCE TEACHING

History

The FAST project was begun under the sponsorship of the Hawaii Science Curriculum Council. This council was formed in October 1966 in response to the recommendations of a curriculum conference, which was conducted by the Hawaii Curriculum Center for the Department of Education in June of that year. The Council was composed of teachers and science supervisory personnel from the public and private schools in the State, members of the College of Arts and Sciences and the College of Education from the University of Hawaii, and representatives of industry.

A survey of currently available and developing science curricula indicated that a bridging program was needed at the intermediate school level to facilitate student transition from the general process programs of the elementary schools to the disciplinary programs of the high schools. A broad outline for such a bridging program was completed in February 1967. Development and writing of the program, now called FAST, began in the summer of 1967 and continues to the present under the aegis of the Curriculum Research and Development Group of the University of Hawaii.

Since its first pilot trials in 1970, there has been an ever-expanding number of teachers and students involved in the program. At the time of this writing, over 150,000 students have taken one or more years of the program. Some of the materials have been translated into Lao, Ilokano, and Japanese. FAST is currently used in schools in Kosrae, Australia, Japan, South Carolina, and California, as well as in Hawaii.

Curricular and Instructional Assumptions

The FAST Program is designed to provide students with the educational experiences necessary to prepare them for participation in the transactions of a dynamic, scientifically and technologically based society. Its guiding assumptions have been drawn from the work of Arthur R. King, Jr. and John A. Brownell.[1]

First, it is assumed that the primary purpose of education is the development of each student's intellectual capacities. It is through development of the intellect that one satisfies an inherent need to know. By increasing intellectual abilities, students greatly expand their personal options for independent thought and action. This also enhances their capabilities to deal with the broad demands of citizenship and career in a changing society.

Second, it is asserted that the intellectual activity of greatest import to our society has grown out of the endeavors that characterize the applied and theoretic disciplines. It is the knowledge of the disciplines of science, mathematics, engineering, jurisprudence, sociology, political science, theology, etc., that shapes our society. Understanding of the structures of the disciplines is essential to an understanding of our society's past, present, and future.

Third, the structure of the disciplines is uniquely suited for instruction. The knowledge produced by the disciplines, as well as their ways of generating new knowledge, have been intentionally crafted for transmission from one generation to the next. Mathematics, engineering, and astronomy, for example, have histories of successful transmission that reach back for at least 300 generations.

Therefore, the curriculum should be modeled to authentically reflect the structure of the disciplines. Within the disciplines the instructional means for expanding the intellect can be found. Using the disciplines of science as a model for curriculum design provides subject matter of proven interest and worth as well as an instructional mode demonstrated to be successful. The time-honored mode of instruction of the disciplines of science involves the acts of knowledge generating, warranting and application under the guidance of a person knowledgeable in the disciplines.

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[1]King, Arthur R. Jr., and Brownell, John A. 1966. Curriculum and the Disciplines of Knowledge, J. Wiley and Sons, New York.

It follows that if the structures of the scientific disciplines are to be used as a model for curriculum design that students must experience the joys and frustrations of pursuing hypotheses and experimentation in the arena of peer critique. Error and misdirection must be understood as components of successful prediction and replication. The power of a well-formulated, supported, and accepted hypothesis must be seen as a tentative product of community judgment. To capture the nature of scientific research and community interaction, the model for student-teacher roles must reflect an interactive leader-colleague relationship rather than the typical passive authority-audience relationship.

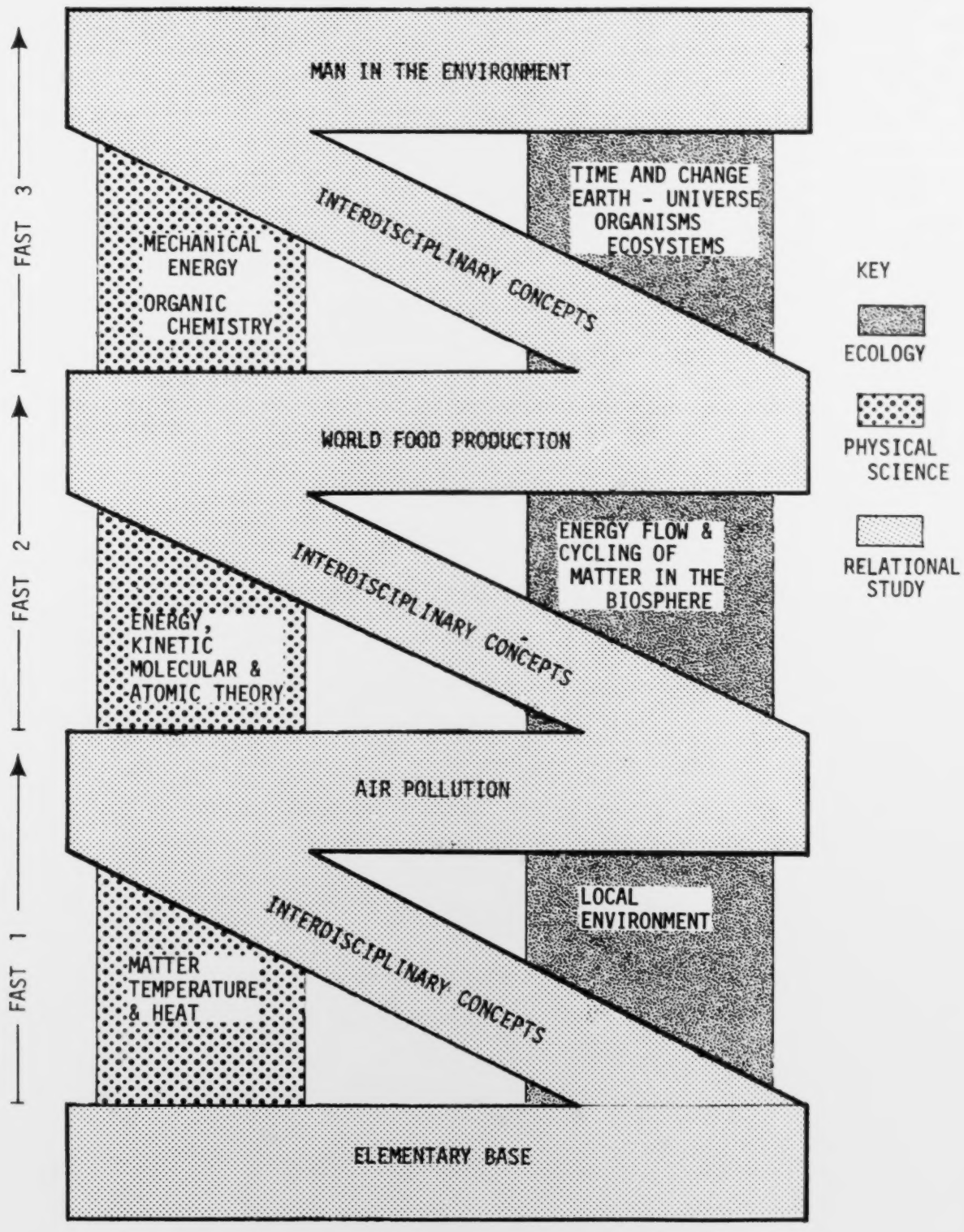
Objectives

FAST is designed to provide investigative experiences and inquiry activities in the physical, biological, and earth sciences, as well as in the application of the knowledge of these sciences to environmental issues. The goal of FAST is the development of a scientifically literate student who has 1) the background necessary for understanding the environmental concerns arising in our technological society, and 2) the foundational tools for further study in the sciences.

The specific objectives of FAST are to increase student:

1. Capability to perform basic laboratory skills.
2. Capability to use the symbolic tools of science.
3. Knowledge of concepts that are foundational to modern science.
4. Capability to engage in scientific inquiry.
5. Understanding of the sequential nature of the history and development of science.
6. Understanding of the relationships among disciplines of science.
7. Knowledge of the nature of science.
8. Capability to apply a knowledge of science to other areas of endeavor.
9. Understanding of the relationships among science, technology, and society.
10. Capability to use scientific knowledge for decision making.
11. Internalization of the values, attitudes, and traits necessary for successful endeavor in science.

General Structure of the FAST Program



Curriculum Design

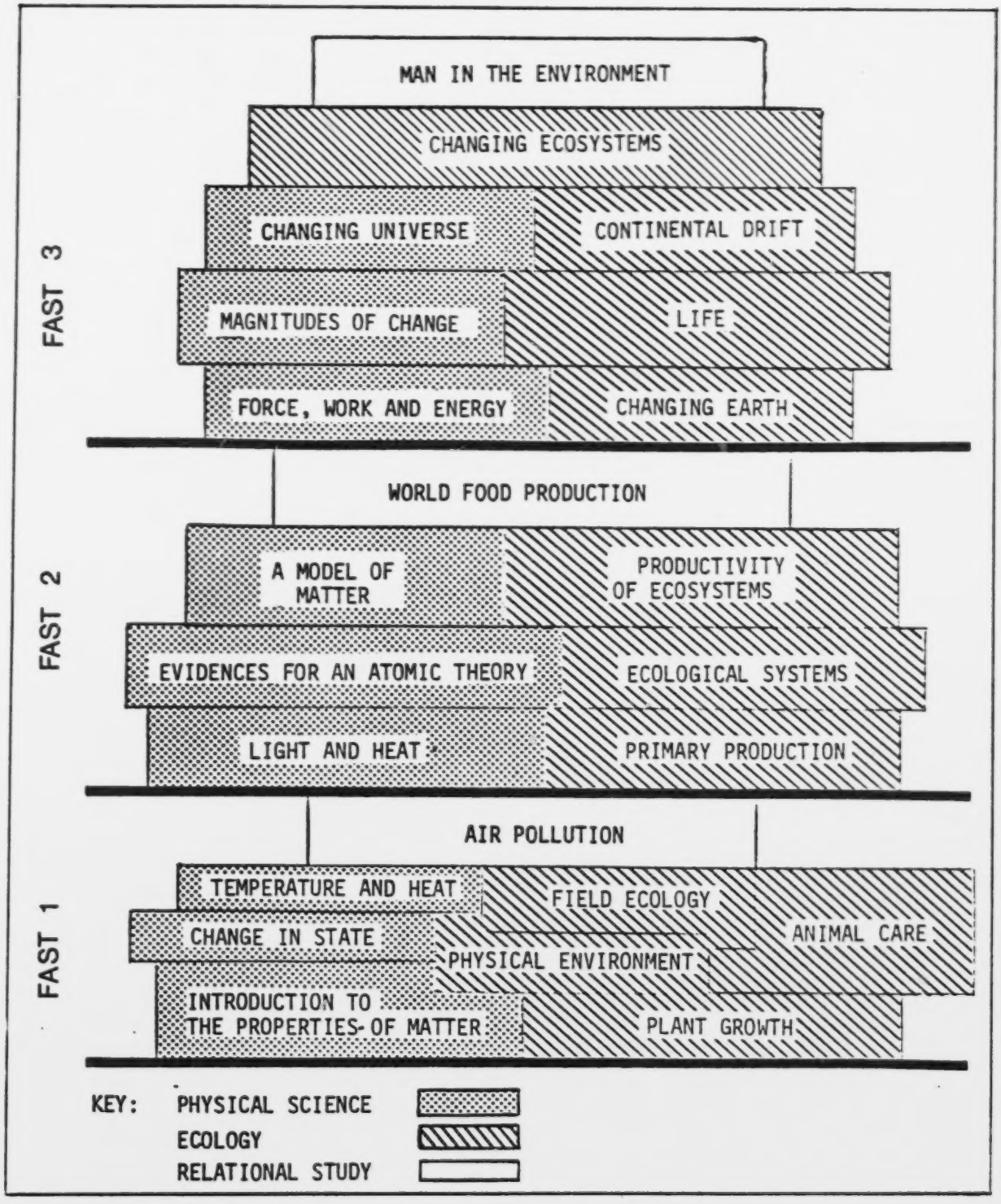
In the FAST Program, the content of several sciences, including chemistry, physics, earth science, and biology, are studied independently and are then brought together in the study of the ecology of the local environment. Throughout the program, the integrity of each of the various disciplines is maintained. The subject matter of the program is organized into three strands, Physical Science, Ecology, and Relational Study. The first two strands provide the formal science content while the Relational Study strand provides a way of viewing the interrelationships between the sciences, technology, and society. The diagram on the previous page shows the general structure of the program.

Scientific content has been selected on the basis of interdisciplinary utility and social relevance. Principles developed in the Physical Science strand constitute the foundations of science and undergird the Ecology strand. The biological and earth science content of the Ecology strand is related to the understanding of principles basic to major environmental issues. The Relational Study strand uses the teaching strategy of interdisciplinary concept reinforcement. That is, concepts and skills developed in one science are used or applied in another, thus showing how all areas of science are interrelated. The Relational Study strand also confronts the student with the problem of how the technologist, social planner, and citizen can use scientific knowledge in making decisions involving environmental quality. See the content diagram on the following page.

The content of the Relational Study is drawn from the fields of philosophy and history of science. It weaves the many parts of science into meaningful whole. The Relational Study points out the inherent similarities and differences in the kinds of inquiry characteristic of Ecology and Physical Science. It focuses on the historical parallels between work developed in the FAST laboratory and work done by the investigators who first grappled with the same concepts. It shows the connectives between the sciences, technology, and the world of the citizen. It also exposes the limitations of scientific knowledge in the arena of social decision. Through this approach, the input of sciences is seen as but one of many factors (moral, ethical, aesthetic, political, etc.) which must be weighed in making decisions affecting society.

FAST is designed to provide common foundational experiences in the concepts and methods of science for students in middle school or intermediate and high school. Special provisions are made for students of lower and higher ability levels. FAST has been carefully crafted to capitalize on the unique developmental characteristics of the adolescent. Students of this age show an increasing capability for abstract thinking and are able to inquire and reflect on the significance of their activities. This is also a time of commitment, when attitudes, habits, and intellectual styles that will strongly influence the remainder of their schooling and adulthood are solidified. FAST seeks to help students develop positive attitudes toward science and useful problem-solving approaches by providing them with a variety of activities relevant to the world that is unfolding before them.

FAST Unit Diagram



Instructional Mode

FAST, in its commitment to modeling the experience of practicing scientists, relies on students operating in a research team to generate the theoretical content of the program. The mechanism for ensuring continuity of the development of theoretic concepts is a carefully planned programmatic sequence of tasks and contexts of inquiry. Such planned encounters allow sufficient time to define categories of events, generate hypotheses, test hypotheses, correct misconceptions, and, ultimately, come to a community or team consensus on the adequacy of explanations.

To achieve successful group generation of an acceptable conceptual structure, between 70 and 80% of the students' time is spent at the laboratory bench or in field studies. The remainder is devoted to an analysis of data, small group or class discussion, literature research, and report writing.

The role of the teacher in FAST becomes one of research director, a colleague who is actively engaged in stimulating and facilitating ever deeper probing into problems. Students become researchers, create hypotheses, do the physical experimentation, organize and analyze data, and develop a team consensus on conclusions upon which study will progress.

The FAST research team approach can tolerate misconception, because the contexts of investigation are carefully sequenced so that hypothesis and conclusion once developed are constantly retested. One of the experiences in FAST is that science involves a process of constant reconstruction of explanation in the light of new findings. As counterweight to the dynamics of theoretic evolution and revolution, foundational concepts of science once defined are seen to generally remain intact. Out of these foundational concepts has come the building of our present scientific enterprise.

II. CONTENT DESCRIPTION OF THE FAST PROGRAM

FAST 1 - The Local Environment

The theme of FAST 1 is the local environment. Students are involved in field and supportive laboratory investigations which identify the components of the environment and focus on the interrelationships between these components. FAST 1 laboratory and field work is designed to capitalize on the excitement of discovery and to get students involved in the activities of science. Through these activities and involvement with science, students not only become aware of their environment, but also gain foundational scientific concepts that are essential for them to function effectively in the technological world of the present and future. Students are encouraged to apply their knowledge to local environmental problems. By involving students in the process of generating scientific knowledge and by providing them with the information and foundational concepts that have a high probability of being of value in their future, FAST 1 is designed to help prepare students to play responsible roles as citizens in tomorrow's world.

Strand Descriptions

Laboratory and field investigations are designed to involve students in the kinds of activities that characterize a modern scientific community. The methods of investigation adhere rigorously to the demands for community validation, with careful attention paid to student-planned experimental designs, the setting up of controls, execution of experimentation, and the interpretation of results.

The problems presented to student research teams are open investigations which often focus on questions for which there are no fixed answers. On completion of the assigned tasks, the student is intentionally left with many quesions unanswered. These questions often suggest approaches to be pursued in subsequent experiments. Other questions are often left to the student's own inquiry.

FAST 1 Physical Science begins with the study of buoyancy, out of which emerge the concepts of mass, area, volume, density, and a definition of matter. Then, changes in the state of matter, pressure, properties of gases, liquids, solids, pure substances, mixtures, and fluids are investigated. Finally, energy in the form of heat is studied with focus on the relationships between temperature and heat.

FAST 1 Ecology seeks to provide an awareness of the local environment by investigating plant growth, animal behavior, and the physical features of the environment. Attention is focused on the interrelationships between plants, animals, and the physical environment through extended studies of a field site.

FAST 1 Relational Study considers the application of physical and ecological principles, as well as socioeconomic concerns to environmental issues. Two alternative units are available for student study. In one unit students study community water resource management. In the other, students investigate local air quality.

Skills

Students learn to manipulate standard laboratory instruments, such as balances, graduated cylinders, thermometers, and heating devices. They practice standard laboratory procedures and observe standard laboratory safety precautions.

Considerable emphasis is placed on research skills, such as planning via flow diagrams, designing and executing valid experiments, keeping data, constructing and using graphs, and clearly communicating results. These skills are viewed as foundational for scientific endeavor.

In addition to the science skills, FAST is also designed to develop and enhance interpersonal skills. Most work is done in small groups. Leadership is shared. The ability to get along with others, cooperate, and get a job done, is developed through example and practice.

FAST 1 Sequence of Units

As the suggested time schedule on the next page indicates, Ecology and Physical Science strands are presented concurrently by alternately teaching short sequences of materials from each strand. There is considerable overlap in presentation of Ecology units, one unit often beginning before previous units have been concluded. This is especially true of investigations which are dependent upon weather conditions.

Ecology Unit 1, Section A, on scarification of seeds with hard seed coats, is designed to be the first experimentation of the Ecology strand of FAST 1. This section introduces students to the laboratory of the biologist and to cooperative group work in carrying out an experiment.

Ecology Unit 4, Field Ecology, is designed to unite all of the Ecology strand into a meaningful whole. Ecology, as defined in the FAST Student Book, is the discipline of science which studies the interactions of plants (Unit 1), animals (Unit 3), and the physical environment (Unit 2). Units 1, 2, and 3 break down Ecology into its biological, geological, and meteorological components, thus allowing closer analytical study. Unit 4, on the other hand, focuses student attention on the total environment. Units 1, 2, and 3 may be viewed as analytical investigations which generate information to be used by students in their studies of field ecology in Unit 4.

The Relational Study is inserted within the Physical Science and Ecology strands and is also taught as the independent Air Pollution and Water Resource Management Units. The culminating investigations draw on skills and concepts from both Physical Science and Ecology, and also consider the factors involved in decision making.

The concurrent and alternating presentation of problems from the Physical Science and Ecology strands provides frequent changes in pace and topics. By studying alternating sequences of materials, students have time to reflect on observations, can see the application of observations in a different setting, and can avoid getting bogged down in the details of investigations. The alternating presentation also allows time for long-term data collection required by many Ecology investigations.

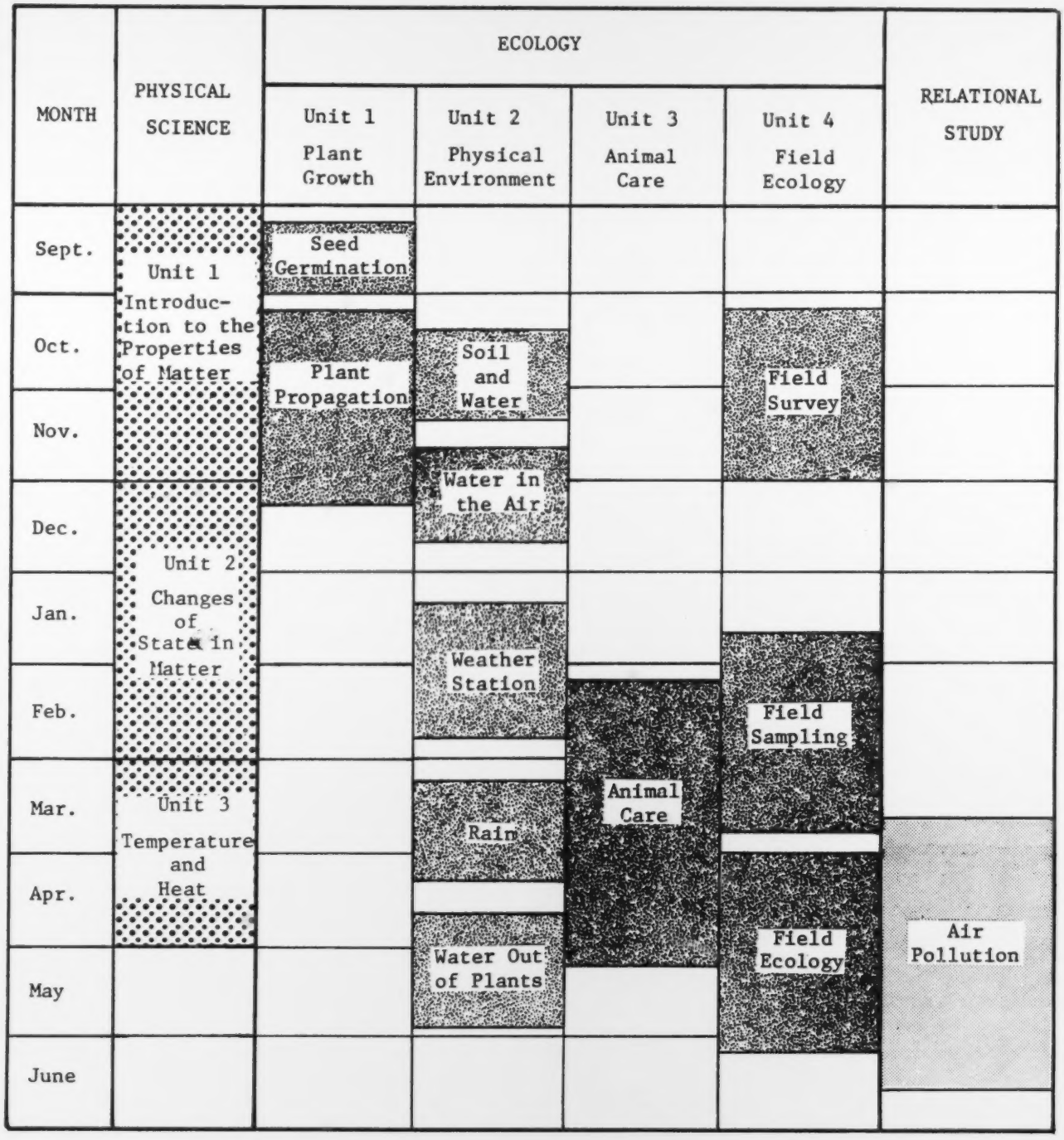
FAST 1 Alternating Ecology Time Schedule

Sections of FAST 1 Ecology can be sequenced in different ways. Such alternative sequences may be dictated by student and/or teacher interest, by weather conditions, or by such things as school schedules, available study areas, etc. The following two pages provide some suggested alternative schedules for FAST 1 Ecology investigations. Other sequences are also possible.

In the Ecology strand, some topics may be omitted. These are usually topics in which environmental conditions make study difficult. In selecting Ecology topics for study, however, the teacher should consider the logical sequence of ideas. Also the teacher should be aware of topics students have already studied in previous courses and topics they are expected to experience in subsequent courses. In preparing students for FAST 2, for example, it is very important that FAST 1 students deal with 1) the concepts of temperature and heat in Physical Science, Unit 3, 2) Ecology Unit 1, Plant Growth, 3) Ecology Unit 2, the Physical Environment, Sections A and B, which deal with soils, and 4) Ecology Unit 4, Field Ecology. FAST 2 investigations in Physical Science and Ecology build on the concepts and skills developed in these FAST 1 investigations.

Physical Science problems are designed to be done sequentially from Problem 1, Liquids and Vials, through Problem 41, Solar Heating Project. Omitting Physical Science investigations or changing the order of their presentation may jeopardize student understanding of the foundational concepts which are developed in this strand.

FAST 1 Suggested Time Schedule



FAST 1 Suggested Time Schedule (Alternative)

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 1 Introduction to the Properties of Matter	Seed Germination			Field Survey	
Oct.			Soil and Water			
Nov.					Field Sampling	
Dec.			Water in the Air			
Jan.	Unit 2 Changes of State of Matter		Weather Station			
Feb.						
Mar.	Unit 3 Temperature and Heat	Plant Propagation	Rain		Field Sampling	
Apr.				Animal Care		Air Pollution
May			Water Out of Plants		Field Ecology	
June						

FAST 1 as a Sixth and Seventh Grade Two-Year Program

FAST 1 is designed to be appropriate for a range of grade levels. Consequently, several school systems have found FAST 1 an ideal program for sixth grade students. However, sixth grade students are less mature, less able to quickly handle abstract concepts, and are less adept in the handling of laboratory equipment than are older students. Therefore, in order to use FAST 1 at the sixth grade level, several adjustments in scheduling and sequencing are required.

Adaptation of FAST 1 as a sixth grade program means essentially covering half of the course in sixth grade and completing the remaining half in greater depth and with augmentation in seventh grade. Since FAST 1 is intentionally designed to contain more investigations than can be completed by most classes in one academic year, it lends itself well to such a two-year course of study. This extended use of FAST 1 over 2 grades ensures that students more completely experience the foundational skills and concepts which are the essence of FAST.

A suggested time schedule for FAST as a sixth and seventh grade program is provided on the following pages. Note that during the suggested sixth grade portion of FAST 1, Physical Science, only Unit 1, Introduction to the Properties of Matter, is studied. Problems in Physical Science are again approached sequentially beginning with Problem 1, Liquids and Vials, and progressing through Problem 17, Weather Balloon Project. Physical Science Units 2 and 3 become part of the seventh grade program.

In Ecology, sixth grade students investigate topics in Unit 1, Plant Growth; Unit 2, The Physical Environment; Unit 3, Animal Care; and Unit 4, Field Ecology. In the study of animals, however, it is suggested that students care for small animals such as mice, rabbits, quail, guinea pigs, gerbils, etc., rather than the insects and similar organisms called for in the seventh grade Animal Care Unit. This will provide experience in handling and caring for small mammals before doing the more sophisticated animal investigations in seventh grade. Unit 4, Field Ecology, should be shortened for sixth grade students and limited to the Initial Survey and quadrat studies described in Section A.

To maintain the structure and philosophy of FAST, a Relational Study Unit comparable to the Air Pollution Unit of FAST 1 has been developed. The Relational Study Unit called Water Resource Management, builds on the water cycle established in Ecology Unit 2, The Physical Environment. The Water Resource Management Unit involves students in investigations of water availability and use in their community. This Relational Study Unit, which can also be used as an alternative to the Air Pollution Unit of FAST 1 is available as a separate publication.

Modifications of the remainder of FAST 1 to complete it in the seventh grade are minimal. Problems in Physical Science, Units 2 and 3, are investigated in sequence. In Ecology, major emphasis is placed on Field Ecology. The Initial Field Survey and Quadrat Studies employed as part of the sixth grade program are repeated. Animal Care studies are conducted on organisms obtained from the Field Ecology study site. Weather stations and weather instruments are used again in the seventh grade, however, this time emphasis is placed on collecting data regarding local air quality in preparation for the Relational Study Unit on Air Pollution.

FAST 1 Suggested Time Schedule (Sixth Grade)

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 1 Problem 1 to Problem 12	Seed Germination			Initial Field Survey	
Oct.			Soil and Water			
Nov.						
Dec.			Water in the Air			
Jan.	Problems 13 & 14					
Feb.	Problem 15 to Problem 17		Weather Station	Animal Care	Repeat Quadrats	
Mar.		Plant Propagation				Water Resource Management
Apr.			Rain			
May			Water Out of Plants		Repeat Quadrats	
June						

FAST 1 Suggested Time Schedule (Seventh Grade)

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 2 Changes of State in Matter				Field Survey	
Oct.				Animal Care		
Nov.					Field Sampling (add soil tests)	
Dec.						
Jan.						Weather Stations
Feb.	Unit 3 Temperature and Heat					Air Pollution Measurement
Mar.					Field Resurvey	
Apr.					Field Ecology	Air Pollution
May						
June						

FAST 2 - Flow of Matter and Energy in the Biosphere

FAST 2 explores the theme of the transfer of matter and energy through ecosystems. Student investigations establish that the processes of photosynthesis, respiration, and decomposition are carried on by living organisms; that there is conservation and cycling of matter in the biosphere; that solar radiation entering the biosphere eventually exits from the system as heat. The role of humans as controllers of forced ecosystems is also studied. From these investigations emerge the realization that all organisms are part of a complex interdependent biosphere.

Strand Descriptions

FAST 2 provides students with a realistic perspective of the human position as an environmental manipulator in a world of finite matter and energy. Students investigate the pressing problems of world-wide food shortages, energy and fuel shortages, and overpopulation. FAST 2 develops the theme that humans can and must plan for the world of the future. Since humans act as decision makers and agents of change, they must consider the technological, social, economic, and ecological implications of their actions. FAST 2 is based on the assumption that students of today must understand the processes and interactions of the various ecosystems of the planet and must recognize a personal commitment and responsibility for environmental quality as we increasingly become citizens of the world.

FAST 2 Physical Science investigations support ecological studies. Physical science begins with an inquiry into the Newtonian physics of light. Students investigate the nature of light, including measurement of the solar constant, absorption, transmission, reflection, refraction, diffusion, color, and the spectrum. A working definition of energy is developed as anything that can be converted into and measured as heat and the relationship between light and heat is explored.

Students then begin a search for evidence for the existence of atoms by analyzing and synthesizing various compounds. These investigations are shown to provide good support at the molecular level for the assumptions of conservation of matter made in the Ecology studies. A brief review of the history of chemistry is also undertaken to search for further evidence in support of an atomic theory. Finally, students investigate the kinetic molecular theory of matter which is then applied to the explanation of various molecular phenomena.

FAST 2 Ecology focuses on matter and energy transfer in ecosystems. Initial studies investigate the interaction of plants and light. Through a series of laboratory and field studies, students identify the process of photosynthesis and generate a model of a producer. Then respiration is investigated as a matter and energy conversion process in both plants and animals. Out of this study, a model of a consumer is developed. The special group of consumers called decomposers is considered by making compost and studying the process of decomposition. The processes of photosynthesis, respiration, and decomposition are then compared. The concepts of interdependence of all living organisms, the cycling of matter in ecosystems, and the flow of energy through ecosystems are developed.

Students then apply their knowledge of the transfer of matter and energy in ecosystems to a real system that they design. They set up either field garden plots, or microecosystems in gallon jars. By manipulating components of the system, a forced ecosystem is created which maximizes the production of one or more products.

FAST 2 Relational Study, World Food Production, develops a realistic perspective of humans capable of manipulating the pathways of matter and energy use in ecosystems to meet their desires. Analysis is made of one or more of the energy problems facing the world, such as food shortage, or fossil fuel shortage. Students are involved in decision making situations in an attempt to confront these global problems and seek solutions to them.

Skills

FAST 2 students build on the skills learned in FAST 1. It is assumed that students know how to handle standard laboratory equipment. Additional practice is provided in FAST 2.

Research skills are emphasized. Students design many more of their own experiments paying careful attention to controls, replication, and other characteristics of valid experimental design. Students are increasingly responsible for identifying problems, formulating hypotheses, designing tests, conducting experiments, preparing data tables, collecting data, and communicating results of their work. There is also an increased reliance on reading as a method of gathering needed information. Further opportunity for developing interpersonal skills is also an integral part of the skills development of FAST 2.

New research tools are also added to the students' expanding repertoire. In FAST 2 they learn how to do chromatography to separate and identify substances; how to generate and identify various gases; how to analyze compounds by heating, blowpiping, electrolysis, and acid analysis; how to test for the presence of carbohydrates, fats, and proteins; and how to measure energy as heat. Students also learn valuable horticultural skills in preparing their garden plots.

Systems analysis is introduced in FAST 2 as a technique to simplify complex problems and to account for components of a system. Systems analysis is used extensively throughout Physical Science and Ecology for cataloging what is known about a system and for visually summarizing relationships.

FAST 2 Sequence of Units

FAST 2 Physical Science and Ecology strands begin where FAST 1 ended and build on concepts and skills developed in FAST 1. FAST 1 Physical Science ends with investigations of the relationship between temperature and heat with particular emphasis on the measurement of heat. It is in Unit 3, Temperature and Heat, that the calorie is introduced. If these investigations were not completed by students in FAST 1, it is recommended that they be undertaken before students begin FAST 2 Physical Science. See the FAST 2 Teacher's Guide for specific suggestions.

As in FAST 1, both Physical Science and Ecology are taught by alternating sequences of investigations in each strand. The Relational Study is much more evident in FAST 2. Concepts developed in one strand are used to investigate new problems in the other strand.

FAST 2 Suggested Time Schedule

Months	Physical Science	Ecology	Relational Study
September	Unit 21 Light & Heat	Unit 21 Primary Production	
October			
November			
December	Unit 21 Evidence for An Atomic Theory	Unit 22 Ecological Systems	
January			
February			
March		Unit 23 Productivity in Ecosystems	
April			
May	Unit 23 A Model of Matter		Unit 2 World Food Production
June			

The main theme of FAST 3 is change over time. The assumption is made that things have changed in the past, are changing now, and will continue to change in the future. By studying change in many different parts of the environment, students not only learn about things which are happening now or have happened in the past, but also can use their knowledge to predict events in the future. The concept of time is expanded back 5 billion years, then forward to the era of the student's own adulthood and beyond.

Strand Descriptions

FAST 3 enters new realms of science different from the activities in FAST 1 or FAST 2. Here there are no final answers, no firm conclusions, not even a certainty of data. Circumstantial evidence replaces "hard" data. Pro's and con's are weighed, considered opinion is supported or denied. Theories are developed which give the best fit to the known evidence. Probabilities and possibilities reaching millions and billions of years into time, and light-years into space, permit no final confirmation or replication of observations.

FAST 3 Physical Science begins with a study of the processes involved in changing the shape of the local environment. Through these investigations principles of weathering, erosion, volcanism, folding and faulting are established. Rates of change are measured and used to explore and expand the concept of time.

Force, gravity, and energy are defined and measured. The interactions of matter and energy are investigated in studies of a changing universe. Theories of the origin and structure of the universe, stellar evolution, the formation of Earth, and plate tectonics are investigated.

FAST 3 Ecology investigates the interaction of life with a changing environment. Once theories have been advanced which suggest conditions necessary for life support, an operational definition of life is developed. The structure of organic molecules characteristic of life are identified. Alternative theories for molecular evolution and the origin of life on Earth are explored, including investigation into the probabilities of how life forms have changed over time.

Focus is then brought to bear on changes in ecosystems and the effect of living organisms on changing environments. Study of the interaction of organisms with their environments show that as organisms and environments change, so do ecosystems.

FAST 3 Relational Study considers the role of humans in changing the environment. The scale of change produced by humans as they gained control over increasing amounts of energy as hunters, agriculturists, and industrialists, is investigated. The course concludes in a series of simulation games with students as decision makers coping with problems such as resource depletion, overpopulation, energy consumption, and other forms of environmental stress.

Skills

FAST 3 students continue to use basic lab skills which were developed in FAST 1 and FAST 2. Further practice in the application of these skills is provided in FAST 3. Opportunities for further development of interpersonal skills are also provided.

In addition to gathering data through experimentation, students increasingly rely on reading and reviewing the work of other scientists to build models of how Earth and its environments have changed over time. Communication of ideas becomes increasingly important both for scientific progress and for student progress. Prediction of future events based on knowledge of past and current events is further developed. Scientific "fact" is seen as tentative and changing when new evidence or new interpretations of old data are considered.

New skills are also learned such as map reading and interpretation, modeling geological features, and measurement of force, gravity, work energy, motion and location. Simulation is introduced as a means of experiencing decision making concerning use of the environment and realizing possible results of decisions that are made.

Sequence of Units

There are eight units in FAST 3. Though numbered consecutively, units and sections within units can be introduced in a variety of sequences. Several of the units are designed to overlap one another in time so that a variety of activities can be used simultaneously to involve students and take advantage of interest and motivation.

Unit 31, The Changing Earth, is designed to introduce FAST 3. The focus of this unit is on weathering and erosion as processes of change in the local environment. As student experimentation of weathering and erosion progresses, study of Unit 32, Force, Work, and Energy, should begin. Here students focus on the measurement of forces and energy involved in physical changes in the environment. Some suggested sequences of units are shown on the following pages.

FAST 3 Suggested Time Schedule

MONTH	UNIT 31 THE CHANGING EARTH	UNIT 32 FORCE, WORK AND ENERGY	UNIT 33 MAGNITUDES OF CHANGE	UNIT 34 THE CHANGING UNIVERSE	UNIT 35 LIFE	UNIT 36 CONTINENTAL DRIFT	UNIT 37 CHANGING ECOSYSTEMS	UNIT 38 MAN IN THE ENVIRONMENT
SEPT. — OCT.	WEATHERING AND EROSION	FORCE	MOUNTAIN BUILDING					
NOV. — DEC.		WORK ENERGY	TIME	HISTORY AND STRUCTURE OF THE UNIVERSE				
JAN.				STELLAR EVOLUTION EARTH FORMATION	CHARACTERISTICS OF LIFE ORGANIC MOLECULES		POPULATIONS	
FEB.					ORIGINS OF LIFE	THEORY DEVELOPMENT	LIMITS TO GROWTH	
MAR.						NEW EVIDENCE	ADAPTATIONS	
APR.							POPULATION INTERACTIONS	ENERGY RESOURCES MAN AND ENERGY
MAY								POPULATION GROWTH SIMULATION GAME

FAST 3 Suggested Time Schedule (Alternative)

MONTH	UNIT 31 THE CHANGING EARTH	UNIT 32 FORCE, WORK AND ENERGY	UNIT 33 MAGNITUDES OF CHANGE	UNIT 34 THE CHANGING UNIVERSE	UNIT 35 LIFE	UNIT 36 CONTINENTAL DRIFT	UNIT 37 CHANGING ECOSYSTEMS	UNIT 38 MAN IN THE ENVIRONMENT
SEPT. OCT.	WEATHERING & EROSION		MOUNTAIN BUILDING					
NOV. DEC.		FORCE WORK ENERGY	TIME	HISTORY AND		THEORY DEVELOPMENT NEW EVIDENCE		
JAN.				STRUCTURE OF THE UNIVERSE STELLAR	CHARACTERISTICS OF LIFE		POPULATIONS	
FEB.				EVOLUTION	ORGANIC MOLECULES		LIMITS TO GROWTH	
MAR.					ORIGINS OF LIFE		ADAPTATIONS	SIMULATION GAME 1
APR.							POPULATION INTERACTION	ENERGY RESOURCES MAN AND ENERGY
MAY								POPULATION GROWTH SIMULATION GAME

III. FAST INSTRUCTIONAL MATERIALS

A variety of student and teacher materials have been developed to both guide and support ongoing student investigations. These materials are listed and described below.

Student Materials	Teacher Materials
Student Book	Teacher Guide
Student Record Book	Instructional Guide
Reference Booklets	Evaluation Guide

Student Materials

Student Book: FAST Student Books consist of worksheets containing problem statements, and suggestions to guide investigations as well as summary questions which focus on generalizations to be drawn from specific investigations. For each topic, students write their own and class observations, hypotheses, data, conclusions, etc., in the Student Record Book or in their own notebooks. Students thus build a running log of the investigations that they and their classmates perform and thus in essence, write their own textbooks. The Appendix of each Student Book provides information on the metric measurement system. It describes instruments and metric units for measuring linear distance, mass, area, volume, temperature, and time. The reference also provides instructions on construction and interpretation of graphs.

Student Record Book: The Student Record Book contains data tables, graph paper, and space for recording notes and observations of investigations presented in the Student Book. The Record Book enables students to maintain a concise log of individual and class activities. The Student Record Book is designed to be placed in a three-ring binder along with the student's own notes. As an alternative to the Student Record Books, students can make data tables and maintain their own logs of class proceedings using a three-ring binder or some similar organizing system.

Student Reference Booklets: To support student investigations, a classroom library of Reference Booklets is provided. These Reference Booklets describe the use of instruments, suggest experimental designs, outline experimental techniques, and provide supplemental information when necessary. A classroom set consists of 15 copies of each booklet. By using Reference Booklets, students practice the skill of using outside references to supplement the information developed in their own investigations.

Reference Booklets available for FAST 1 are:

Plant Propagation: Describes various ways of propagating and maintaining plant growth. It also provides suggested investigations for students to carry out for each propagation method. Propagation methods included are: bulbs, cuttings, seeds, seedlings, underground plant parts, grafting, air layering, and hydroponics.

Weather Instruments: Provides directions for construction of a weather station and weather instruments such as rain gauge, hygrometer, wind vane, and anemometer. Also included are directions for setting up instruments to measure air quality.

Animal Care: Describes how to construct cages and other environments for keeping a variety of animals found on the school campus.

Field Mapping: Provides directions for making detailed scaled maps of a school campus study area, including mapping of contour lines.

Sampling Methods: Describes how to determine population size by various sampling techniques.

Air Pollution: Provides general information on measurement, effects, and control of common air pollutants.

Air Pollution, Regional: Describes local and state air pollution problems, legislation, and control measures.

Reference booklets available for FAST 2 are:

Chromatography: Describes procedures for performing chromatographic separation of pigments using inexpensive materials and techniques. Both paper chromatography (using filter paper) and thin-layer chromatography (using silica gel) are described. In addition, directions are given for preparation of leaf pigment extracts.

Components of Biomass: Gives directions on conducting simple tests for the presence of starch, sugar, protein, amino acids, fats, phosphates, carbon, and water in plant and animal biomass.

Composting: Describes procedures for making both aerobic and anaerobic compost. Detailed descriptions of aerobic and anaerobic decomposition processes are included. Also suggests methods for investigating the decomposition process.

Gases: Describes the properties of a variety of gases investigated in FAST 2. It also describes methods of generating and identifying each gas, and how to remove each gas from a closed container. This booklet provides the data on which students draw in designing their investigations of gases involved in photosynthesis, respiration, and decomposition.

Elements and Compounds: Provides directions on how to identify elements and compounds by their physical and chemical properties. It also describes the properties of some selected elements and compounds.

Field Productivity: This booklet consists of several parts. The first two sections give directions for planning a garden using PERT diagrams and decision theory techniques. The remaining sections provide information on soil tests, water requirements, nutrients, pests, and pesticides useful in growing healthy crops.

Reference Booklets available for FAST 3 are:

Changing Universe: Provides a narrative on the history of astronomy, current cosmological theories, stellar evolution, formation of elements, and early Earth atmospheres.

Components of Biomass: Gives directions on conducting simple tests for the presence of starch, sugar, protein, amino acids, fats, phosphates, carbon, and water in plant and animal biomass.

Continental Drift: Describes the history and controversy surrounding the evolving theory of plate tectonics. Shows how ideas and people interact in developing a new theory.

Molecules of Life: Traces the early history of organic chemistry in the works of Wohler, Berzelius, Kekule, Gerhardt, and others. It involves students in developing the logic of the tetrahedronal distribution of bonding sites on the carbon atom, and in building models or organic molecules including simple sugars, proteins, and fats.

Organism Maintenance: Describes how to establish populations of various plants and animals in classroom environments. It provides suggestions for investigations of the effects of possible limiting factors on these populations.

Population Effects: Describes the interactions of several populations with their environments. It includes discussion of parasite-host relationships, use of biological controls, and other population interactions.

Teacher's Guide: For the teacher, the logic connecting topics and sequences is presented in the Teacher's Guide. There are separate Teacher's Guides for FAST 1, FAST 2, and FAST 3. Each guide is keyed to the investigations in the Student Book. The Teacher's Guides include teaching suggestions, advice on classroom procedures, and detailed discussion of the conceptual and practical development of the corresponding Student Book as well as lists of needed equipment and chemicals, suggested time schedules, and other information helpful in successfully carrying out the program in the classroom.

Instructional Guide: The Instructional Guide describes the overall philosophy, objectives, and design of the FAST program. In addition, it describes the various components of FAST and provides suggestions on scheduling, sequencing of units and topics, and on strategies for classroom organization and management.

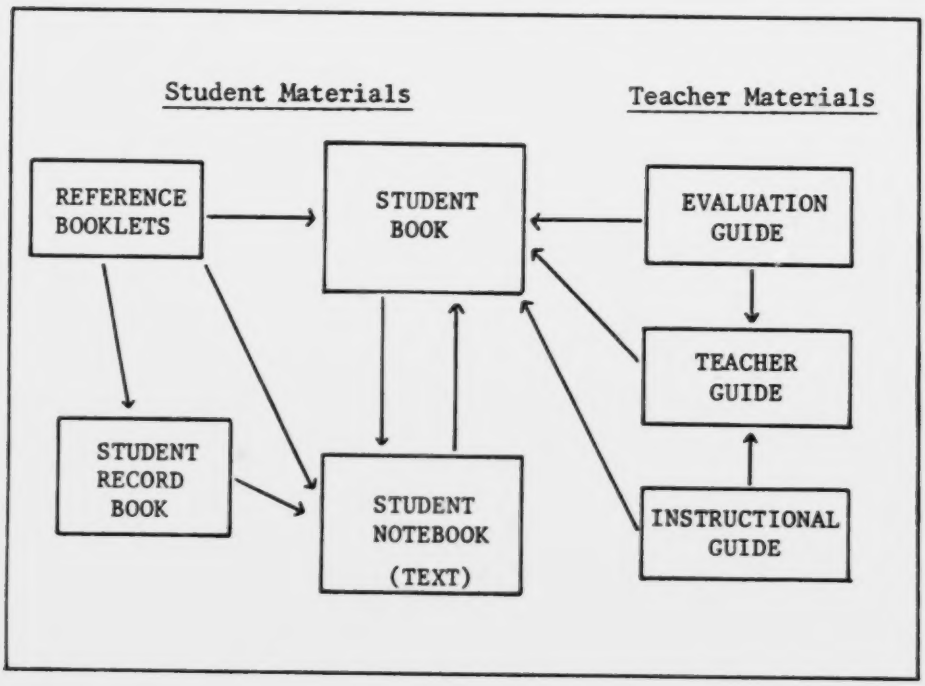
Evaluation Guide: Describes the kind of student evaluations which are built into the FAST program and how they can be used to help students develop to their greatest potential. Also included are the student tests designed to be used in the program. The Evaluation Guide has two components:

Student Evaluations - These tests are designed to assess laboratory skills and understanding of concepts. Teachers are encouraged to use these tests as a means of involving students in self-evaluation.

Progress Records - Also included is a series of Class Progress Records and an inventory of skills and concepts which can be used as an individual Student Progress Record. These Progress Records are designed to help students and teachers know which concepts and skills have been mastered and which should be worked on to meet the expectations of the program.

Support Design and FAST Materials

The figures on the following pages show how the FAST Instructional Materials are designed to support one another. The Student Book and Student Notebook are seen as the central focus of students and teachers, since these materials guide progress through the course.



Instructional Materials Format

Wherever possible, a similar format for written materials has been used in all three strands of FAST. Though there are occasional exceptions, the format employed is described below.

Student Page Format

TOPIC NUMBER AND TITLE

Background

A brief recap of related work done.
Introduction of new ideas.
Introduction of new vocabulary.

Problem or Activity

A question which is the focal point of the investigation or a statement of work to be done.

Procedure

Steps to be done in the investigation.

Summary

Analysis and interpretation of the results of investigations; drawing conclusions; summarizing activities.

Challenge

Investigations of related work which go beyond the given problem; sometimes provided as a lead-in to the next problem; sometimes used to implement the Relational Study.

Teacher's Guide Page Format

UNIT DESCRIPTION

UNIT NUMBER AND TITLE

RATIONALE

Describes why the unit is included in the program.
Describes how the unit relates to other units.
Provides a statement of the objectives of the unit.

OVERVIEW

Generally describes content and student activities of the unit.
Describes how various sections of the unit fit together.

STRATEGY

Gives suggestions on teaching, such as how the unit might be introduced, techniques that might be employed, time of the year, and weather requirements, etc.

SECTION DESCRIPTION

TITLE OF SECTION

RATIONALE

Describes the goals and objectives of the section more specifically than the Unit Rationale; describes how the section relates to other sections.

OVERVIEW

Describes the content and student activities of the section.

STRATEGY

Gives suggestions on teaching, such as how the section might be introduced, techniques that may be employed, etc.

SUGGESTED TIME SCHEDULE

Provides information on approximate time requirements of each problem.

DIGEST

REVIEW

A. (General statements reviewing pertinent
B. ideas developed previously.)

VOCABULARY

(Lists of new words introduced in the problem.)

Single boxes indicate teacher responsibility

INTRODUCTION OF NEW WORK

A. (Suggested teacher approaches to
B. beginning the new topic.)

STUDENT ACTIVITIES

Problem: (Problem statement from the student page.)

or

Activity: (Statement of work to be done.)

(Short flow diagrams of procedures and apparatus.)

A. (General statements of student procedures.)
B.

Double boxes indicate student responsibility

SUMMARY

A. (General statements of how to analyze results and information
B. which should be derived from the experiment.)

CHALLENGE

Thought provoking question or investigation.

Graphics Used in the Teacher's Guide

In the Teacher's Guide, various graphics are used in the left margin to identify special information.

This graphic style indicates that a transparency master has been provided. The master may be a class data sheet or a diagram of student instructions.

This graphic design indicates that a page in the Teacher's Guide may be duplicated and distributed to students. In most cases these pages contain too much information to make good transparencies.

The single circle graphic also surrounds the number of the optional pages.

This square points out places where there are relationships between the strands. For example, the symbol shown may appear in the Ecology Teacher's Guide and indicates that information relating to the topic being considered is also covered in Physical Science investigations 3, 4, and 5.

IV. CLASSROOM ORGANIZATION AND MANAGEMENT

A research-team model is used for class organization in FAST. The teacher is a research director-facilitator, setting tasks, asking questions, and giving suggestions for further investigations. The teacher maintains an atmosphere of inquiry. This means that the teacher role changes from disseminator of information to facilitator of group involvement and learning. A summary of teacher and student responsibilities is given below.

The FAST Teacher:	The FAST Student:
1. Is the research director-facilitator who coordinates the day-to-day classroom activities, sets tasks, encourages, prods, and keeps inquiry open.	1. Is the researcher working to explain the raw data of experimentation and the implications of findings in social contexts.
2. Causes the student to focus on laboratory and field techniques, experimental design, hypothesis formation, generalization, and practical implications of research.	2. Observes, formulates hypotheses, designs experiments, and seeks out the practical significance of research.
3. Provides needed materials and directs an efficient, safe classroom-laboratory facility.	3. Maintains a safe and functional experimental environment.
4. Arranges for student access to the laboratory, field and other sources of information, and provides adequate opportunity to complete assigned work.	4. Uses research as a primary source of concept development and realizes that research may be done in the field or laboratory, or through various information dissemination media.
5. Provides incentive and adequate equipment for the student to pursue open-ended experimentation.	5. Explores a given idea as extensively as the practicalities of time allow.
6. Is alert to the intellectual difficulties of students and arranges task assignments, grouping, and presentation to facilitate maximum development of each student's potential.	6. Accepts challenge and works to extend personal capacity.
7. Engages students in self-evaluation.	7. Seeks to evaluate personal achievement.
8. Encourages mutual sharing of ideas and labor.	8. Develops the attitudes of a participant in a scientific community.

Suggestions for Using the FAST Program

There are some general suggestions for teaching FAST that are stressed in the Teacher's Guide and during the Teacher Training Institutes. These points are important enough, however, to bear emphasizing.

1. The roles of both the teacher as a facilitator and students as researchers required in FAST are departures from the traditional roles of teachers as active knowledge conveyors and students as passive acceptors. Patience is needed by both teacher and students as they develop in these new roles.

2. In order for the FAST program to achieve its fullest potential, teachers must be constantly aware of the need to help students:

   a. Organize.
   b. Summarize.
   c. Make connections between investigations.
   d. Keep sight of short- and long-range objectives.

   Suggestions for organization of each investigation are contained in the Teacher's Guide. Regular review of these suggestions will be of great help especially during the first year of teaching FAST. The summary questions located at the end of each investigation are particularly designed to help accomplish the tasks above. They should be treated as an integral part of every investigation and used as a springboard for discussion.

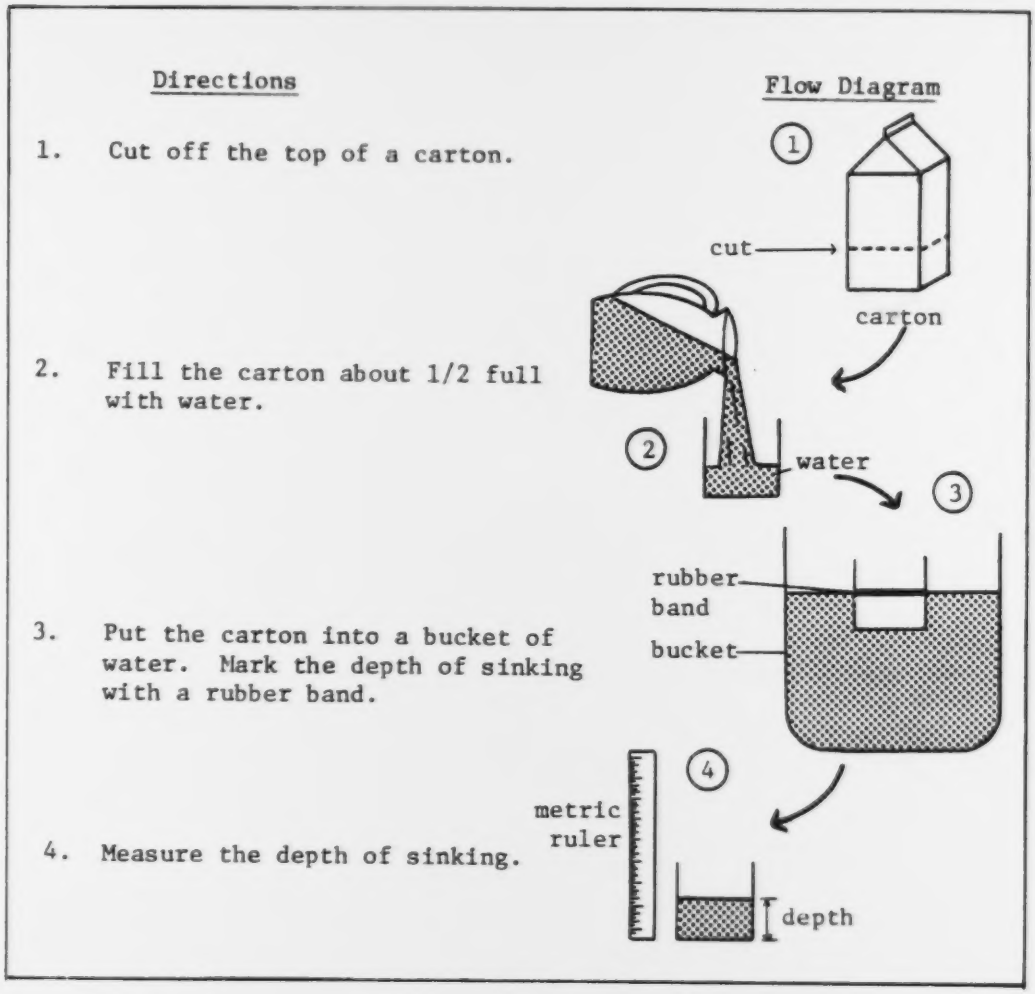
3. Any "hands-on" science program requires much preparation and organization to be effective. The burden of preparation can be lightened through the cooperation of a self-directed class. Laboratory routines should be established from the very first day so that all students are aware of their personal and shared responsibilities in the FAST classroom.

   Teachers are encouraged to help themselves by helping students to assume as much responsibility as possible for laboratory maintenance, set up, and organization. Student lab assistants or a FAST Club often prove helpful.

4. Peer teaching quite naturally develops in the FAST classroom and should be encouraged. Through teaching, students gain a deeper understanding of skills and concepts. Often, just having learned something new themselves, students can communicate just mastered skills and concepts better than their teachers.

5. By their very nature, FAST materials are meant to be dynamic and adaptive. Teachers should feel free to use these materials within the context of their own experiences and professional judgment, and are encouraged to personalize, adapt, extend, and innovate in the same ways they would with any other instructional program.

6. Using flow diagrams is a proven technique for quickly checking on student readiness to perform laboratory investigations. A flow diagram is a pictorial representation of written directions or procedures. A sample flow diagram is shown below.


Directions
Flow Diagram
1. Cut off the top of a carton.
cut
carton
2. Fill the carton about 1/2 full with water.
water
3. Put the carton into a bucket of water. Mark the depth of sinking with a rubber band.
rubber band
bucket
4. Measure the depth of sinking.
metric ruler
depth

Requiring students to sketch flow diagrams of their laboratory procedures before beginning work ensures that they have read the directions. The presence of the flow diagrams in the students' binders is also an aid to the teacher who, with a rapid glance down the column of sketches, can determine if students have understood the directions given them. Sketching flow diagrams results in clearer understanding of directions than providing students with commercially illustrated directions. For details of complex pieces of apparatus, students should generally refer to diagrams in the Student Book.

FAST 1 students are introduced to flow diagram techniques and given increasing responsibility for their production in each succeeding unit. By the time students are in FAST 2, they should be able to read down a column of laboratory directions and, without further assistance, sketch appropriate flow diagrams.

7. Relationships between parts of the program must be regularly raised to consciousness by review. Unless the teacher causes students to periodically pause to look for connections between investigations and concepts within a strand and between strands, there is a danger that they will characterize science as a collection of unrelated parts. Establishing a sense of continuity and connection constitutes one of the major tasks of the Relational Study.

   The kinds of connections to be drawn out in review are:

   a. The connection between sub-components of evolving concepts. For example, in developing buoyancy, the relationship between mass and volume of an object and the density of the fluid in which it is placed must be carefully laid out.

   b. The use of concepts developed in one area of science for use in another area of science (the instrumental use of concepts). For example, the use of buoyancy to explain the movement of parcels of air in the atmosphere.

   c. The use of knowledge developed in science to help guide social decisions.

In showing relationships, it is important to have students contrast the use of techniques and the kinds of data derived in different areas of science. For example: graphs of biological data provide evidence of individual differences among organisms, while graphs of physical systems are far less variable.

The Digests in the Teacher's Guide are very helpful visual tools to use for such review. After students have completed a topic, digests can be posted on the bulletin board to give a visual reminder of the development of concepts.

The Student Notebook

The students' notes and Record Book contitute their texts. It is extremely important for students to begin on the first day of class to keep organized notes on observations, hypotheses, summary questions, and vocabulary. Sixth graders especially will need direction, encouragement, and help in organizing and keeping their texts up-to-date.

The following are suggestions for developing record keeping skills:

1. Data should be entered in the tables provided in the pages of the Student Record Book. These pages should then be placed in a three-ring binder. Additional pages will be needed for class notes and answering summary questions. These too are added to the notebook, thus building a log of individual and class investigations.

2. Some teachers have found that keeping the student notebooks in class during the week reduces confusion and makes work more available for teacher checking. Notebooks can be kept in class in cardboard boxes, in dishpans that can be stacked, on a standard bookshelf, rolling cart, etc.

3. Students should develop regular habits and standard procedures for note keeping. For example:

    a. Always state the problem. Get students in the habit of writing the objectives of the problem or activity being worked on, before they do anything else. Put the objective on the board or on a chart so that it can serve as a constant reminder for students.

    b. Be sure data tables are understood by each student. If Record Books are not used, tables should be prepared before beginning laboratory work. Students should understand that they may need to make additional notes of unusual observations or new hypotheses as they investigate.

    c. During the summary or during other times of class discussion, have a class "recorder" put important points on the board so that everyone can see and record them.

    d. Be sure that a vocabulary list is kept and added to as new words and concepts are introduced. A class vocabulary list that is posted for reference is also helpful. New words are listed in the Digest of each investigation in the Teacher's Guide.

4. Encourage students to review their notes to make corrections and additions. It should be made amply clear that record keeping is a scientific skill like reading a balance. Note keeping should not be emphasized to the point of frustration, however.

5. Check notebooks frequently. A checklist that can be added to student notebooks at the beginning of the year is helpful and will provide consistent guidelines for completing work. A suggested form is provided below.

STUDENT NOTEBOOK CHECKSHEET

	Date Checked						
1. Investigations are in order.							
2. Investigations are complete.							
3. Graphs and data tables are labeled.							
4. Graphs and data sheets are readable.							
5. Notes are complete for problem statements.							
observations.							
class discussion.							
summary questions.							
anomalies.							
vocabulary.							
6. Errors have been corrected.							
7. Conclusions and hypotheses have been revised to reflect class discussion.							

Planning for Effective Group Interaction

In the FAST laboratory-classroom, the teacher is continually interacting with one or more groups of students. A group may be the entire class or some segment of the class. Group sizes vary according to the objectives of the learning situation. Discussion involving the entire class may be appropriate for some lessons, but inappropriate for others. The following pages describe some alternative ways of grouping students and providing opportunities for effective group interaction.[1]

ARRANGING FOR GROUPS

Arranging for effective group interaction requires special preparation and planning. Attention must be paid to 1) the general environment in which the groups will operate, 2) the seating and working space, 3) the size of the group or groups to best undertake the task at hand, 4) the selection of group members and 5) the mechanics that will be used to share group information with the remainder of the class.

The Environment - It is most important to provide an environment that is conducive to good group interaction. Circulate among the groups, try to identify needs, offer help if you must. But at the same time, relax, allow the groups time to interact before expecting them to act. Below are some ideas which enhance the comfort and positive emotional climate of groups.

1. Create an environment which is attractive and pleasant to work in. A cheerful environment makes group members feel more at ease and cooperative.

2. Be sure there is proper ventilation and lighting in the room. A stuffy, or poorly lighted room causes drowsiness and uneasiness which will be reflected in less effective group interaction.

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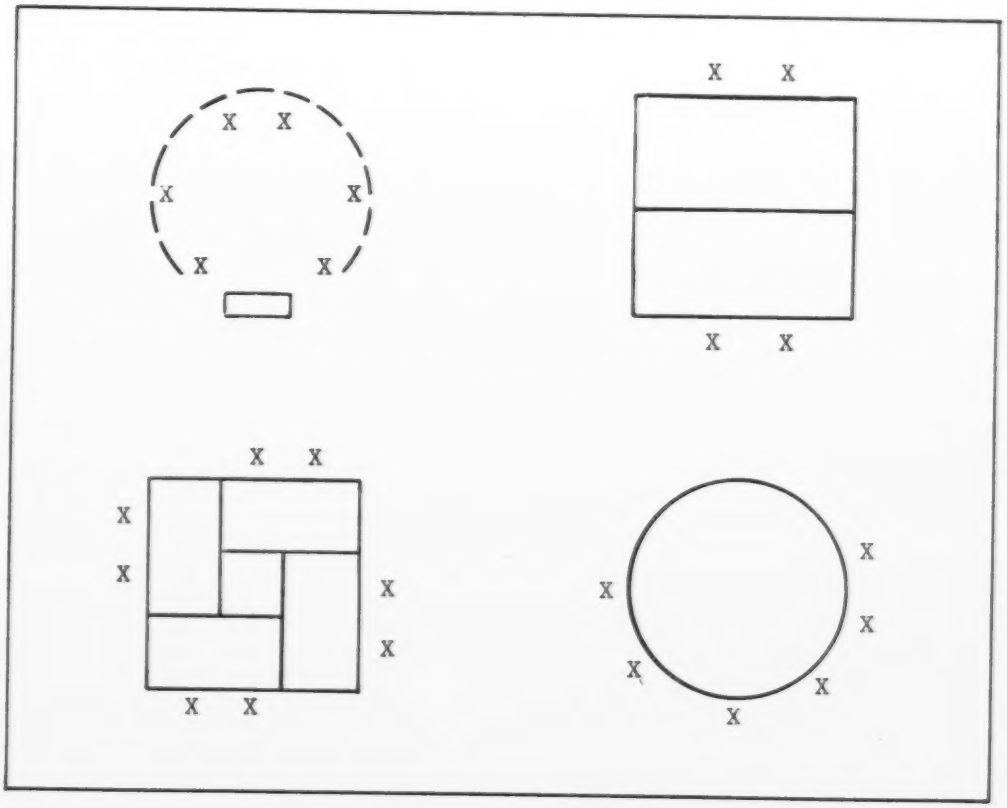
[1] Some of these materials have been adapted from Investigating Your Environment series developed by the U.S. Forest Service.

Seating - The arrangement of people in a group is another important factor to be considered. Circular arrangements have the advantage of allowing each person to see every other person. If possible, table space should be provided for all individuals to facilitate writing of notes and recording discussions.

The physical arrangement not only suggests the kind or level of participation, but may even dictate it! For example, in the typical classroom seating arrangement the students face only the teacher, thereby providing only for good exchange between the teacher and the student. Alternative arrangements encourage more student participation. The diagram below shows some alternative arrangements.



Group Size - The size of a group is determined by the type of task to be done by the group. For some activities and/or discussions, large groups are appropriate. For others, smaller groups are more appropriate. The objectives of the group task should determine the group size. The teacher must decide on the most appropriate group size, whether to break a large group into smaller ones or to bring smaller groups together to build a large group. Some examples of how the task or activity may suggest size are given below.

1. Conveying Information - When it is necessary for teacher to give directions, present new information, summarize class activities, etc., groups of 25-30 students may be most appropriate. This is the traditional mode of classroom instruction and is illustrated as shown below. In such groups, individual participation is usually limited.

2. Open-ended Discussion - Groups of 10-12 people seem optimum for open-ended discussions about controversial topics, especially those calling for opinions. Such groups are large enough to ensure diverse opinion, yet small enough so as not to preclude participation. Interaction of this type is diagrammed below.

3. Problem-Solving - Whenever it is desirable for a group to focus on a particular problem, share ideas, get consensus and develop problem-solving strategies, an appropriate group size seems to be about 4-6 people. Groups of this size are used extensively in field project work. Such a group is small enough to ensure a high level of individual involvement without the danger of too much divergence from the task at hand. Once the problem to be considered has been introduced, the teacher may wish to join a group or simply allow students to tackle the problem on their own. This type of group interaction may be diagrammed as shown below.

4. Laboratory Problems - Most of the laboratory problems in FAST call for a team of 2-4 students. This number allows each student to become involved in the operation of the investigation and provides the necessary hands to perform needed tasks. Further, it ensures an intellectual critical mass, so that investigations do not get stymied for want of an idea.

5. Short Discussion - Pairs are best used when students are to discuss something quickly, without distraction, or when the highest level of involvement is required, such as in laboratory work. A diagram of this type of interaction is shown below.

Ease of Management

A single class group is usually easier for a teacher to manage than several smaller groups, particularly at the start of the year. Here the focus of the students is generally on the teacher and on one topic. However, large groups tend to limit discussion since it is difficult for all individuals to participate.

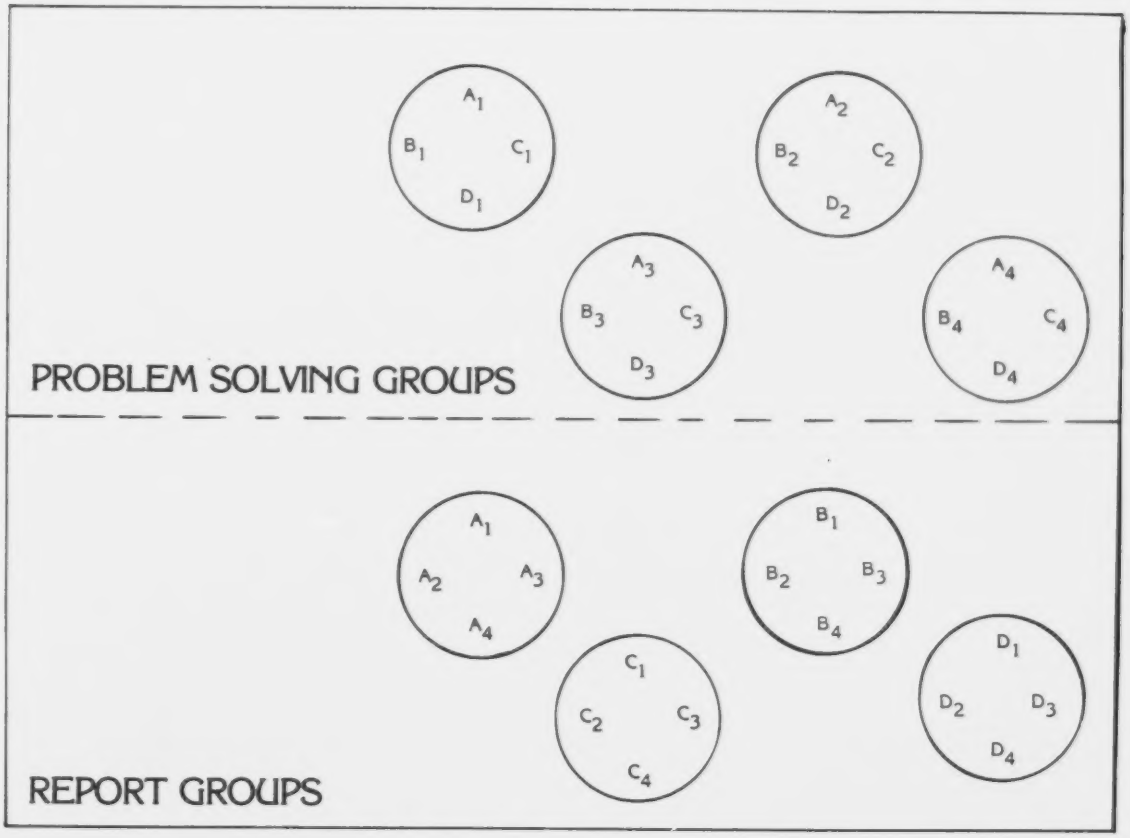
When smaller groupings are used the teacher is no longer the focal point; the topic or problem being discussed is. The teacher then must be willing and able to adjust to a new situation in which many different activities may be going on in the classroom at one time. Smaller groupings require the teacher to carefully plan lessons and questions which generate student involvement with the subject matter, and which clarify the objectives and tasks of each group. Furthermore, the teacher must be cognizant of what is happening in each group.

The strength of the small group is that it gives greater opportunity for group members to participate in discussion and to contribute ideas. Smaller groups also provide opportunities for individuals to assume responsibility for their own learning, to participate in decision making processes, and to practice skills of interpersonal communication.

Selection of Group Members - How groups are selected is also important to the social-emotional climate of the group. Group members may be teacher-selected or self-selected (either by personal preference or interest). If the teacher selects and assigns students to particular groups on some basis other than random assignment, care must be taken to account for sex balance, interest and abilities of students.

Certain topics may require special skills or talents. If so, arrangements should be made so that at least one member of the group possesses these talents. Such skills and talents may then be learned by others in the group. For example, poor readers may be grouped with good readers on tasks that require reading so that by helping one another the group may successfully act upon a task. Having students work with different groups at various tasks enhances their opportunities for making new acquaintances and for developing interpersonal communication skills.

Information Sharing and Small Groups - When several small groups in a classroom are working on a similar topic it is often desirable for them to share the information they have generated. This can be done by a variety of techniques. For example, one member of each group may share with others the problems they have encountered. Another technique that may be used is diagramed on the next page. Such an arrangement eliminates the need for large group reports.



Here members of the problem solving groups are assigned to report groups. Each report group will have one member of each problem solving group.

ESTABLISHING THE GROUP

Care must be taken in the initial stages of developing functioning groups to be sure that students have a clear picture of what is expected of them. Equally important, it is essential that the group members know one another. If the group has been formed for discussion or a long-term project, leadership roles need to be specified. Finally, the group must have a direction and purpose for being. This is found in its charge.

Expectations

The role of group activity should be spelled out before students are divided into groups. It is important for students to recognize that a research team approach to inquiry is being used to search out the foundational ideas of science. This will require group cooperation and personal commitment to do one's share of the work assigned.

Initial Leadership

In many group activities no leader in name is necessary to the dynamics of the lesson. This is true in the case of lab team activity and paired discussion. However, when organization for group projects is necessary, or if discussion in groups of four or more students is undertaken, it is generally wise to have a recognized group leader. This establishes responsibility and accountability for the product called for in the lesson.

Once the group has been established, a group recorder should be selected by the group or assigned by the teacher. The recorder should be an objective person capable of accurately writing down the group interactions. The recorder's role is to accept and report or record the contributions of group members. Care should be taken by the recorder to write down what is heard without modification; to record the essence of contributions without censorship.

The Charge

The final product of a group can be no better than the charge under which it operates. It is essential that in the earliest stages of their functioning that the group have a clear picture of what they are to do. Many times this is a statement made by the teacher, sometimes by the program materials, sometimes by the decision of the group. In all cases the first point on the agenda after organization is reviewing the charge for clarity if it is given, or formulating the charge if it is the responsibility of the group.

STAGES OF GROUP INTERACTION

Every group has to spend time and energy learning how to work together. Usually some interpersonal feelings develop between members during their learning process, especially when the group is first formed. It takes time for members to learn how to fit into the group and how to contribute to the group. Things often seem "all mixed up," and the group members may become disturbed and discouraged, even aggravated at each other. It may help to know that these are natural stages in the development of effective group interaction, that these interpersonal feelings tend to follow a predictable progression or sequence, and that in most cases the group will soon become productive and efficient.

Described on the next few pages are some of the stages that groups may go through during this developmental process. Though these stages generally apply to all groups, no one stage is essential. Some groups may begin at stage 3, 4, or even 5. Other groups may never get past stage 3 or 4.

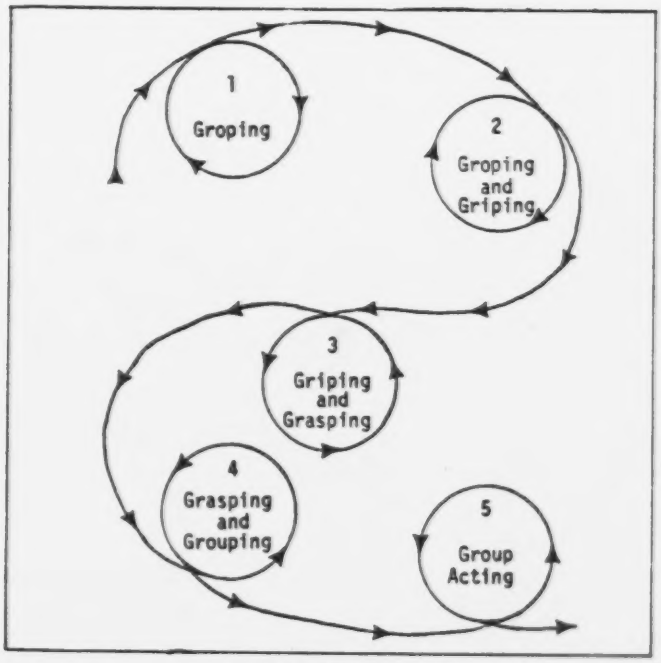
1. Groping Stage - When a group of students is first finding out how to work together they may not all agree. They do not know and do not understand one another well enough to really trust each other. They still have to identify each other's skills, knowledge, and attitudes. They may feel uncomfortable and even frustrated.

2. Griping Stage - A group tends to get discouraged when members cannot seem to work together, when there is not much progress, or when their attempts are frustrated and frustrating. They may attack one another verbally, play negative roles, and block group action because they are uncomfortable. Though members have different strengths and interests, they generally all want to do a good job and to be liked by others. The desire to do the job well usually provides the necessary ingredient to hold the group together and allow them to progress to the next stage.

3. Grasping Stage - With patience and guidance, ideas and suggestions start to fit together. The group begins to agree on questions and everyone begins to feel more comfortable with the realization that they are getting somewhere.

4. Grouping Stage - When students get to know each other, they begin to understand and appreciate how other members operate and contribute to the tasks being undertaken. The group begins to function well, members begin to assume building and maintenance roles to keep the group operating at a high level, and a surge of enthusiasm spreads through the group. A feeling of "my group" begins to emerge.

5. Acting Stage - When the group is in full swing, members play constructive roles, leadership is shared, and everyone participates. Ideally, all group members are sharing in making plans and decisions and are learning together. They feel that this is a good group with which to work.



Stages of group interaction.

These stages characterize how group members feel. They are independent of the content being addressed by the group. It is important for the teacher to recognize that a certain amount of negative feeling is natural when a group first tries to work together, and to realize that despite such feeling, groups can move ahead toward more harmonious relations between members. As members get to know one another better, a group gradually becomes their group, because they have shared plans and work, and have tried to practice ways of behaving which are cooperative, considerate, and friendly.

The teacher's role during the time of group formation is to try to identify at which stage the group seems to be, and to facilitate movement to a more productive stage. The teacher tries to see that everyone feels included and accepted and tries to get the group to address the task at hand. This is done by suggesting procedures, focusing and refocusing group attention on the topic, clarifying statements and direction, and summarizing progress to date. In general this can be facilitated by carefully planned questioning strategies. Suggestions on how a teacher or other group leader can facilitate group action are included in the section "Facilitating Group Discussion."

CHARACTERISTICS OF EFFECTIVE GROUPS

There are probably many other factors in addition to those already discussed which contribute to the effectiveness of groups. Without exception, however, communication is the most important, for without good communication there can be no effective group interaction. Good communication is based on three main factors; 1) open sharing of ideas with others, 2) listening attentively to the ideas of others, 3) feedback to the speaker to ensure clear understanding of what is being said. Following are some of the characteristics of effective groups which reflect accepting, open communication.

1. The effective group knows why it was formed and what it is supposed to do.

2. The effective group openly communicates personal feelings and attitudes and does so because members recognize that such open communication helps the group function even better.

3. The effective group makes sure that all members express themselves on important decisions, and are not dominated by the leader's ideas nor of any of its members.

4. The effective group listens attentively to ideas expressed by its members.

5. The effective group recognizes that all members and their ideas are important.

6. The effective group is accepting of the fact that each member is unique and has personal needs, which must be met.

7. The effective group recognizes the different talents and abilities of each member and tries to make use of these talents.

8. The effective group recognizes that group success is the responsibility of all members, not solely resting on the leader.

9. The effective group shares the responsibility for leadership with each group member assuming a leadership role at one time or another.

STUDENT GROUP LEADERSHIP

The key to maintaining high quality group involvement is the group leader who initiates and maintains good group interaction. The successful leader consciously builds and maintains a positive social-emotional climate within the group through personal behavior, attitudes, actions. Experience in the FAST program has shown that the skills of effective leadership can not only be learned by teachers, but can also be learned by students.

The Effective Leader

It has often been assumed that group leaders possess certain special traits or characteristics. Many studies have been made in an effort to correlate the leadership capacity or potential of an individual with personal attributes. While some definable personal characteristics have been linked to leaders in certain situations, these studies have not been successful in providing a formula for leadership selection. The present view is that leadership is functional or "job centered." We should ask then, "What does an effective leader do?" rather than, "What kind of person will be a good leader?"

The things that a good leader does fall into three general categories; personal behaviors, communication skills, and organization. Some of the characteristics in each of these categories are listed below.

Personal Behavior - The effective leader

- -establishes an accepting and trusting environment.
- -shows sensitivity to the feelings of the group.
- -shows sensitivity to the needs of the groups.
- -listens attentively.
- -recognizes that each member of the group is important and needs recognition.
- -recognizes that leadership can be shared and is not to be monopolized.
- -refrains from arguing.
- -refrains from criticizing or ridiculing members' suggestions.

Communication Skills - The effective leader

- -makes sure that goals and objectives are clearly defined.
- -makes sure that everyone understands not only what is needed, but also why it is needed.
- -makes good communication within the group a routine part of the job.

Organization - The effective leader

-establishes an environment which is physically comfortable.
-develops and identifies long-range and short-range objectives.
-breaks big problems into smaller ones.
-shares opportunities and responsibilities.
-plans, acts, follows up, and evaluates.

Nature of Leadership

What, then, is leadership? In basic terms, leadership is the activity of helping others work toward common goals or purposes. Leadership may be regarded as a series of functions that 1) help individuals to feel comfortable and at ease in a group including looking after the physical setting and getting acquainted, 2) build and maintain a group over a period of time, 3) help to set and clearly define objectives, 4) achieve a cooperative esprit de corps allowing a group to work toward attaining set objectives and 5) get a job or task done.

Group leaders must consciously build and maintain a positive social-emotional climate within the group before meaningful participation by all members of the group can take place. The social-emotional climate of a group can advance or impede group operation. People tend to be cautious about exposing their ideas to value judgments of others.

Art and Craft - The ability to work effectively with groups in a leadership role can be learned through conscientious effort, study and practice. Leadership is both an art and a craft. The skills of the craft are learnable. Therefore, by understanding and conscientiously practicing some of these principles, anyone can become a better leader. The art of leadership develops through personal application of leadership skills.

Shared Leadership - All members of a student group should, ideally, at some time or another assume a leadership role. This not only contributes to the growth and development of both members and leader, but also pools the skills and abilities of the entire group, promotes a spirit of unity ("my group" feeling), intensifies each member's feeling of responsibility for group maintenance, gives members a stake in goals and objectives they help establish, and promotes a feeling of satisfaction as each group member shares common achievements.

The Teacher and Shared Leadership

The teacher's responsibilities in arranging for situations in which leadership can be shared with students include:

a. Clearly defining goals and objectives as identified and agreed upon by the group.

b. Establishing an accepting and trusting environment in which group members are free from criticism or ridicule.

c. Establishing a setting where group members are socially at ease and physically comfortable.

SUMMARY

The ability of a group to achieve its goals depends to a great extent on whether or not its members can communicate well among themselves and with others outside of the group. It is important that group members feel comfortable both emotionally and physically. After the group has been formed, has begun to feel at ease, and has identified its task, it may begin operating at any one of the number of stages. Eventually, as interaction becomes more directed and constructive, the group will begin acting on the task at hand, making decisions, recommendations, etc.

The group leader is the most important factor in facilitating group interaction and discussion. The leader must know and practice behaviors that are accepting, encouraging, and supporting of group members. In addition, the leader must know how to listen and how to respond to group members and help them direct their efforts toward the task at hand.

These leadership skills are important for students to know. In the FAST classroom many different kinds of grouping are used. The teacher is not always the group leader. Leadership is often shared by having students function as small group leaders. The techniques of effective leadership should then be shared with students and opportunities provided for each student in the class to practice the role of group leader.

Facilitating Group Discussions

In most classrooms, discussions play a very important role in the learning process. The FAST classroom is no exception. Approximately 20 to 40 percent of FAST class time is spent in small group or class discussions.[1] In addition, since most work in FAST involves team activity, there must be extensive discussion between students to successfully complete work.

Discussion is expected to hold a prominent place in the FAST instructional system. Discussions are generally used at the beginning and end of each laboratory or field investigation. At first, it is the teacher's responsibility to generate and stimulate class discussions. Ideally, as the year progresses, increasing responsibility for discussion will be assumed by students as they become more aware of the role of discussion in inquiry.

Discussions may be used for many different purposes, including

-to give guidance and direction
-to review concepts and skills already in the student's background
-to introduce and identify a new problem or area of investigation
-to generate hypotheses
-to plan experimental procedures
-to analyze and interpret data
-to assess and revise hypotheses
-to formulate and analyze conclusions
-to summarize an activity or experiment

It is important to keep in mind that roles described here are, under many circumstances, equally appropriate to students, however, students must be taught how to carry out their roles.

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[1] For further description of grouping and the group leadership role, see the section, "Planning for Effective Group Interaction."

THE FACILITATOR OF DISCUSSION[1]

The discussion leader is referred to here as the "Facilitator." The facilitator's job is to assist groups to work through the various stages of group interaction[2] and to complete a given task. In this role the facilitator proposes, suggests, invites, questions and is generally concerned not only with the content of the discussion, but also with the feelings of each group member. The facilitator tries to promote good group interaction, stimulate responses, and help the group generate its own data. Some of the ways to facilitate group interaction are described below.

Encourage Participation - If a person is reluctant to enter the fray, an invitation to disagree, recap, summarize, or just jump in and contribute may be all that is needed. Such invitations act to encourage by letting individuals know that their contributions are wanted. Involvement assists an individual to feel that they are a member of the group.

Group discussion often involves disagreement with one's peers. Take advantage of such disagreement and encourage active participation by seeking divergent ideas. Everyone should be invited to give their views and, most importantly, should be asked for evidence to support their views. Disagreement is particularly fruitful if there is no pressure for closure, no voting, no concern when an impasse is reached.

In FAST the moment of impasse is to be cherished for the crucial question can then be asked. "How do we test our ideas?" A side benefit accrues to students who learn early that in solving social problems there are no easy answers, no "one right" answer or conclusion, and there are different ways to process the available data.

Support Group Members - Be supportive of all group members participating in a discussion. Be particularly supportive of those students who have problems of entry into the mainstream of group interaction, such as:

-the person who is suddenly unable to answer when asked for a response
-the shy person who offers irrelevant information on their first attempt
-the unpopular person whose every comment is attacked by someone
-the person whose ideas are always just given by the last speaker
-the person who needs a helping, supportive hand

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[1] Some of these materials have been adapted from Investigating Your Environment series developed by the U.S. Forest Service.

[2] See "Planning for Effective Group Interaction."

When a person makes an error of specific fact, ask another question to allow the person to correct the error. Another way, if disagreement is routinely encouraged, is to ask the group for a different point of view. Whenever possible, refrain from direct correction to avoid inhibiting participation. When students become apprehensive about the reception of their thoughts, they begin to offer only those answers that they consider acceptable to the teacher.

Remember than anyone's head holds numerous "false" ideas, scientific, economic, political, historical, etc. These erroneous ideas become apparent only when expressed. If students never opened their mouths or wrote down these thoughts, no one would ever know what "right and wrong" ideas they have. Getting the wrong ideas out into the open is one advantage of discussion. When the teacher recognizes that a large segment of the group displays serious misunderstandings about a particular topic, it becomes possible to plan learning activities to rectify these misunderstandings.

Listen Attentively - One of the most difficult things for a facilitator (and a group member) to do is to listen--to really hear what is being said. Spoken words do not always convey what is really intended. In addition, whatever one hears is filtered through one's own thoughts and experiences and, therefore, is often distorted. An effective facilitator must consciously listen to statements made by group members and help all group members understand them.

Listening may be passive and silent. Saying nothing indicates acceptance. Keeping quiet and allowing students to say what they choose encourages them to say more. Nonverbal clues such as smiling, nodding, etc. also indicate acceptance of ideas. In addition, verbal clues are often used to assure the speaker that someone is really interested and listening. Such phrases as "Uh-huh," "I see," etc., indicate to the speaker that you are listening.

Listening attentively may also involve interaction with the speaker. The facilitator may feed back information to the speaker to clarify or to gain greater insight into the true meaning of the speaker's statements. Such feedback tends to ensure understanding of what is being communicated.

ALTERNATIVE FACILITATOR ROLES

One facilitative role that is perhaps most familiar to teachers is that of the directive facilitator. The directive facilitator guides or leads members of the group to a predetermined point, for example, to discover a generalization. To be effective, the directive facilitator must have some knowledge of the content being investigated by the group and must plan ahead how the investigation or discussion will progress. This style of leadership is characteristic of the FAST teacher throughout the course, but is most extensively used during the early part of the year. The skills necessary to be an effective directive facilitator are difficult for students to learn or feel comfortable with at this point in their development, since this role does require a knowledge of the content being discussed.

There are many discussions in the FAST classroom, however, in which there is no predetermined end point. The objective of the discussion is to get the group to interact, to bring out as many ideas as possible, in short, to keep discussions open-ended. Such discussions require different leadership skills, those of a nondirective facilitator. The nondirective facilitator encourages individuals to participate in the group discussion without biasing their input or guiding the direction of the discussion. This role is not as familiar to teachers as the directive facilitator. It requires the teacher to be accepting and trusting of the students' ideas, while at the same time keeping the discussion focused on a set topic.

On the other hand, the nondirective facilitator is not dependent on content knowledge since it is the responsibility of the group to supply information and ideas. Because of this, the nondirective facilitator's role is more easily learned and practiced by students than the directive facilitator role. Remember, that only as FAST students are provided an opportunity to learn the leadership skills associated with this role can they be expected to accept responsibility for leading group discussion in the classroom.

The following pages describe some of the techniques that are characteristic of directive and nondirective facilitators. The roles are not mutually exclusive, so that it may be difficult at times to determine which role a group leader is exhibiting. Techniques of one kind of facilitator are often employed successfully by the other kind of facilitator. The distinctions made here are for the convenience in describing alternative behaviors of group leaders.

The Directive Facilitator

Many times the group leader may be at a loss to know how to keep a group moving or a discussion alive. By developing and using certain discussion techniques, the leader can raise the level of discussion and increase the interaction among participants. Like all group leaders, it is important that the directive facilitator accept responses, encourage participation, support group members, and listen attentively to what is said.[1] This section includes some discussion techniques designed to help one acting as a directive facilitator to deal more effectively with comments and responses to questions asked of the group.

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[1] Ibid.

Questions That Develop Content

In addition to setting and maintaining a favorable social-emotional climate in the classroom, the directive facilitator must keep the discussion moving in the desired direction. This is most effectively done by asking questions. However, asking good questions requires planning and practice. There are many different kinds of questions that can be asked. Some are appropriate at one point in a discussion, but inappropriate at others. Knowing how to ask good questions, what kinds of questions to ask, when to ask them, and what responses to expect, are all part of the discussion skills that the effective directive facilitator knows and practices. The facilitator should always plan carefully beforehand what questions will be asked. Writing them down often helps to clarify direction and increase the probability of clear, well-stated questions which can be acted upon. Several different types of questions are described below.

1. Focusing Questions - Focusing questions initiate discussion or produce major shifts in a discussion. Preplanned questions can pace and direct the discussion to areas that need to be considered. Some examples of focusing questions are:

> "What we want to do first is to analyze the data. Let's start by looking at the first two columns of the data sheet. Can anyone see anything common to both columns?"
>
> "Let's look at our chart for ways these animals are alike; no more on differences."

Sometimes in setting a focus, a facilitator inadvertently poses a double focus. This can result in confusion in the group as to what the topic of discussion is. For example:

> "What can you say about these animals after seeing the film; what would you expect to find if we went to the reef?"

Refocusing is essential at times, especially for people who wander off the track easily. The focus question may be repeated, or written on the board. Rewording may be necessary to start the flow of discussion if the original phrasing is misunderstood by those attempting to respond. Most refocusing is related to maintaining the discussion of the topic.

> "Now, what were we discussing a moment ago?"
> "How does that relate to the subject?"

2. Clarifying Questions - Asking for clarification is one way of responding to content. The clarifying question elicits the meaning of unfamiliar terms or the rephrasing of disconnected, fuzzy statements to ensure common understanding. For example:

"Can you be more specific?"
"What do you mean by things?"
"Can you say that in another way?"
"Can you give us an example?"

3. Extending Questions - The extending question pushes for elaboration in response to the content of a comment. The facilitator may be probing for alternatives, additions, analogies, and explanations, mainly on the same level of the original contribution.

"Can you think of any other differences?"
"Can you tell us some more about soil erosion?"
"Is there anything else that you would like to mention?"
"Does heat have properties that are similar to those of any other thing that you know?"

4. Lifting Questions - The technique of lifting the level of discussion is the most difficult one to learn and one most often overlooked by a facilitator. Questions can be preplanned to lift the discussion away from the concrete toward the broad generalization. Between the preplanned lifts, there are unplanned, unforeseen occasions for abstract thinking if the facilitator recognizes the moment and inserts a why-type question.

Seizing these opportunities to lift the level of discussion reflects a facilitator's artistry. Individual lifting questions usually cannot be prepared in advance because the direction of any one person's contribution is unpredictable. These are the spontaneous questions for pursuing thinking with one person. Through one, or a series of questions, the facilitator may often assist a person to build a chain of relationships that may, or may not, end in a generalization or inference.

"Are heat and light connected in some way?"
"From the two lists can you find a common property?"
"Accepting that the properties listed on the board are common to gases and liquids, what hypothesis might be made to explain winds and ocean currents?"

5. Summarizing Questions - When a person elaborates on an idea at great length, or the meaning of a statement is buried in an extended discourse, it is often a good idea to ask for a succinct restatement.

"How can we put what you have just stated on the board?"
"Can you give us the main idea of what you are saying?"

Use of summary questions at the end of a discussion or class period can be one of the most exciting and important parts of each lesson. Such questions are designed to allow participants 1) to discuss the implications of what they have learned, and 2) to generate their own concepts and generalizations about what they have done.

Examples of Questions Specific to Scientific Inquiry

In the FAST classroom, most discussions between the teacher and individual students or small groups, involve questions that direct student attention to the formal aspects of scientific inquiry. These include questions designed to help students identify the problem to be investigated, to guide students to devise a plan of investigation, and to help them analyze the results of their experimentation. Some specific types of questions that might be used in each of these areas are given below. Can you identify focusing (F), clarifying (C), extending (E), lifting (L), and summarizing (S) questions in these lists? A given question may serve more than one function.

Possible questions for identifying a problem are:

( ) "What is puzzling about the phenomena being observed? What is happening here? How does this work?"
( ) "Which observations can you explain? Which ones can't you explain? What do you know about this already? What else is like this?"
( ) "What are the conditions under which the phenomena are taking place?"
( ) "How is your observation related to your previous experiences? Have you seen something like this before?"
( ) "What do you know about this phenomenon? Does this remind you of anything else you have done?"

Possible questions to stimulate hypothesis formulation are:

( ) "How might the anomaly be explained?"
( ) "Do you know a related problem we have solved? Could you use it? Would it help solve this problem?"
( ) "What are some possible solutions to the problem or anomaly? Which solution seems the best or most reasonable to you?"
( ) "How might you separate this complex problem into simpler parts?"
( ) "How might you restate the problem to make it easier to explain?"

Possible questions for designing experiments are:

( ) "What are the variables? What are the points of change in this process?"
( ) "How might the variables in the experiment be controlled?"
( ) "What kinds of new data or information would support your hypothesis?"
( ) "How much data is necessary for valid interpretation? What data is needed to find a solution?"
( ) "What controls are necessary?"

Possible questions for analyzing an experiment are:

( ) "Which data are relevant to the problem? What data really belong here and what are unnecessary?"
( ) "How might you explain the data that contradict your hypothesis? What about data that contradict your conclusion?"
( ) "Have you taken into account all necessary variables in testing your hypothesis? Did you check out all the loopholes?"
( ) "What are the possible sources of error in the experiment?"
( ) "What are the possible interpretations of your data? What other ways might someone else interpret your data?"

The Nondirective Facilitator

Another of the many roles that the FAST teacher plays is that of a nondirective facilitator. The nondirective facilitator does not direct the discussion, but rather tries to promote group responses, help the group generate its own data, develop a group value system, etc. This type of facilitator does not impose personal interpretations, value systems, or answers on the group, but helps the group to generate consensus. As with the directive facilitator, the nondirective facilitator is concerned that every member feels included and accepted, but attempts to remain personally neutral on matters concerning the group task. The nondirective facilitator may employ some of the types of questions characteristic of the directive facilitator, but in general the questions are more open-ended and offer less guidance during discussion.

The nondirective facilitator role may also be used by a student when the class is meeting in small groups. The skills of leadership required to fulfill this role are more easily learned and practiced by students than the directive facilitator role, since the nondirective facilitator does not depend on the knowledge of content.

The following are some things that the nondirective facilitator should keep firmly in mind when leading group discussions.

1. Plan Ahead - The facilitator should always plan carefully beforehand how to lead the discussion. Think through the questions to be asked. Write them down. Select the best questions to address to the group. Aim to establish connections between ideas from previously learned information or experiences and new ideas of members of the group. Plan how to help the group members see how previous learning and experiences may be applicable to the new task.

2. State a Problem Clearly and Concisely - As soon as possible after the group has convened aim to get members to define the question to be discussed. A sharply defined question helps to focus group attention on the objectives to be met. See that the question is clear to everyone. Help to clarify any misconceptions.

3. Suggest a Problem-Solving Approach - If necessary, suggest a way of attacking the question or problem. Solicit suggestions for change or alternative ways of approaching the problem. Get commitment and acceptance from the group to adhere to a plan of action, then proceed to follow that plan.

4. Accept and Clarify Communication - In general, try to accept all responses and statements. This is important since it encourages individuals to contribute further. Relate one idea to another. For example, you might say something like "If I understand it correctly, your idea would add to Ann's by . . . "

Accept incomplete ideas. Ask for further development of the idea from the individual or the group.

Point out when an individual's contribution is cut off and invite completion. "I'm afraid we may have cut Karen off. Did you have any more you would like to add?"

The way in which a facilitator responds to a question or statement can either enhance communication or prevent it. Judgmental responses, those that reflect a person's personal opinions and values, may show either approval or disapproval. Examples of both kinds of statements are given below.

Approval: "That is a great idea. I'm certainly glad you are in our group."

Disapproval: "That wasn't a very smart thing to say."

Both kinds of judgmental statements inhibit individual participation. Some people will not contribute for fear of being disapproved of; others may not contribute for fear of not receiving approval.

Alternately, nonjudgmental responses do not reflect opinions or values and, therefore, contribute to the establishment of a more accepting social climate within the group. Nonjudgmental responses may seek more information ("When was the last time that happened?"), reflect a person's feelings ("The lack of government action is disturbing you?") or paraphrase content ("In other words, you think that this is questionable data?")

5. Accept Feelings - Accept feelings as well as content. Try to interpret feelings and clarify them for the group. "Your feeling is that . . . "

When there is conflict in a group, someone, rather than an idea, is often under attack. People tend to say "I don't agree with YOU," rather than "I don't agree with your IDEA." Emotional feelings often get confused with intellectual content.

The facilitator should try to interpret both the ideas and the feelings being communicated. Try to see the situation objectively. Interpret feelings as objectively as possible. "You feel frustrated? Uneasy? Confused?" "What is it about this idea you disagree with?"

A facilitator should also accept his own feelings. Rather than expressing feelings emotionally, or exploding them before the group, try to interpret your own feelings and state them as objectively as possible. "I feel frustrated at not being able to progress more quickly." Assist other group members to express their feelings in the same way.

6. Keep the Discussion Focused - In any group interaction, the discussion may drift from the main topic from time to time. Point out that the discussion has drifted. Restate the original question or paraphrase it such as "My understanding is that we were discussing . . . " Interrupt the speech maker as tactfully as possible. Invite contributions from other group members. If some important point is being neglected, point it out.

7. Summarize and Clarify Direction - Take time every so often to draw loose ends together. Be as fair and accurate in summary as possible. Call attention to unanswered questions. Suggest what the next steps might be.

   Allow time for group members to discuss the implications of what they generated during the discussion. During the summary activity participants should generate generalizations about what they have done. Close the discussion with a summary of the major accomplishments.

TECHNIQUES THAT REQUIRE CAUTION

Some discussion techniques can have either positive or negative effects on group participation and discussion. Used appropriately, these techniques can help the facilitator guide discussion and learning, and challenge group members to think carefully about their responses. Used inappropriately, these same techniques may destroy group interaction and limit discussion. Such techniques, therefore, must be used with a thorough knowledge of their effect and with caution.

Verbal Rewards

The directive facilitator commonly employs verbal rewards both to support group members and direct discussion. This is a very subtle area, but with certain guidelines, verbal rewards can be very effective in facilitating discussion. The tone of expression is very important, since the emotional overtone of a question or response to a question can either encourage or inhibit participation. An example of a verbal reward is given below.

T: "What industries would we find in Honolulu?"
S: "Pineapple packing."
T: "All right, what else?"
S: "Shipping."
T: "Very good, Johnny!" (You guessed what was on my mind.)

Such an exchange is likely to inhibit people who do not feel that they are very good at guessing what is on the teacher's mind. Generally, avoid the overreward, the overly explicit, overly-generalized reward, such as: "Excellent, Frank. Wonderful, tremendous work, very good." Overreward has the effect of binding, rather than freeing the discussion. Many persons will be reluctant to respond for fear they will not receive it.

The most effective rewards are an implied acceptance of the people and their ideas. Alternatively, the facilitator, in response to Johnny's answer, could have said: "Any others?" A statement such as this keeps the possibility of discussion open, rewards the student by accepting contributions, yet allows termination if no additions are made.

Verbal Repetition

Repeating is a common technique used by many people leading group discussion. This occurs when the facilitator repeats everything each person in the group says.

T: "What did you just see?"
A: "A hawk."
T: "A hawk. Did anyone see anything else?"
S: "A dove."
T: "A dove. Did anyone see anything else?"
S: "A deer."

Repeating may facilitate discussion of certain topics with some groups since it allows students to hear what has been said. Students often do not realize the import of what they are saying unless they have an opportunity to hear what it sounds like. Repeating not only allows students to hear what they have said, but it also allows other members of the group to reflect on and think about what has been said.

Repeating, however, may detract immensely from the effectiveness of the leader and the discussion. It may restrict group interaction since all responses must go through the facilitator. This, in turn, may mean that no one has to listen to anyone else since the facilitator will repeat everything anyway.

If repeating becomes limiting to good discussion, there are several things that can be done to correct it.

1. A simple technique to avoid repeating is to ask the person to say it again so everyone can hear. Refuse to repeat the response. Ask the person to repeat it three times if necessary.

2. Accept the response and do not say anything. By nonverbal behavior, indicate openness to additional comments.

3. Instead of repeating, say, "Anything else? Any other comments?"

In group discussion, students should be talking to each other, not just to the facilitator. By placing the responsibility for making statements heard and listened to on the group members the discussion is kept from being completely leader-centered.

Restricting Words

Words are often used which inadvertently restrict or distort the openness of the discussion. For example:

"What important things did the film show us?"

Now the person must guess what the facilitator thinks is important. The facilitator could alternatively ask:

"What did the film show you?"

However, a restricting question may have an ordering effect on a discussion, especially if students have been giving poorly considered answers or gaily spouting trivia. A restricting word produces a restraint which may be desirable or undesirable, according to the circumstances.

To avoid restricting words, write down ahead of time the major questions that will be asked during the discussion This does two things. First when the question is on paper it can be analyzed ahead of time to weed out restricting words. Second, if the question is written down there is less chance to "ad lib" and throw in extra words that may be confusing.

Leading Questions

Leading questions suggest how the facilitator wants the group to answer. Examples of leading questions are:

"It would be a good idea to pave that street, wouldn't it?"

"Of course the best way to do it is to walk to work, right?"

Such questions can be used effectively to direct discussion toward a desired endpoint or to challenge students to think. In certain groups, leading questions can be used to stimulate discussion by forcing the discussion to an obviously incorrect conclusion. Members of the group will then respond to the conclusion and may be able to point out why it is incorrect. Such use of leading questions must obviously be used with caution.

On the other hand, leading questions may restrict open discussion because the group has to decide what to answer to gain acceptance from the facilitator. In addition, the facilitator may have difficulty in judging the quality of the information received because answers have already been suggested.

Loaded Questions

A loaded question traps a person. The student is caught no matter how he answers the question.

"Have you stopped throwing chalk?"
("Yes, I have" or "No, I haven't.")

No matter what, the student must admit that at least once they threw chalk.

"When are you going to stop being so stubborn?"

These are the classical "Have you stopped beating your wife?" questions.

This type of question can be used to cause members of the group to think. These are trick questions that are best used by the experienced faciltator. One must be cautious in their use since they too, can restrict discussion.

Multiple Questions

In the enthusiasm to emphasize the importance of a question, the facilitator often elaborates with additional questions and ends up by switching the focus from the original, intended question. An example is given below:

"What was the substance that showed the most violent reaction?
"Which reaction produced the most heat?"

This is usually caused by not writing down ahead of time the questions to be asked.

TIME TO THINK

A most important element in any discussion is allowing time to think. Many people find it extremely difficult to tolerate silence. But remember, thinking processes are sometimes slow and painful. Wait for a response. When a prolonged silence ensues, support the person by saying something such as:

"Would you like to keep working on your problem, or would you like someone else to help you?

If the student decides to resolve the problem alone, be sure to call for a response when the solution is finally reached. The same procedure may be followed when a student says:

"I know what I want to say, but I can't say it."

Research carried out by Mary Budd Rowe and others over the last decade has clearly shown the effects on student and teacher behaviors in science classrooms where students are allowed time to think. In inquiry science classes such as FAST questioning is a vital part of the instructional process. However, Rowe found that the average amount of silent time a teacher allowed to pass between question and response (what has now become known as wait time) was just one second. Further, the average wait time between student response and teacher response or another question was only .9 second. Viewed another way this means that the average inquiry science teacher asked from 3 to 5 questions each minute, or over 200 questions in one class period. This is inquisition, not inquiry.

Rowe found that increasing wait time to just 3 seconds (say one thousand one, one thousand two, one thousand three) had significant effects on the following student behaviors.

1. The length of student responses increased.

2. The number of freely offered and appropriate student responses, unsolicited by the teacher, increased.

3. Failure to respond, "I don't know," or no answer, decreased.

4. Inflected responses decreased indicating that students were more confident of their answers.

5. The number of speculative responses increased indicating that students were more willing to think about alternative explanations.

6. Teacher centered show-and-tell decreased and student-student comparing of data increased.

7. Students made more inferences from data.

8. The frequency of questions raised by students increased and the number of experiments they propose increased.

9. The frequency of responses by students rated slow by their teachers increased.

Increases in wait time also resulted in important changes in the following teacher behaviors.

1. Teachers became more flexible in their responses to students. They were more willing to listen to diverse answers.

2. Teachers' questioning strategies became more manageable. While the number of questions decreased, the variety and quality increased.

3. Teachers raised their expectations for students who had been previously described as slow.

If a question is asked of students in a group and they just sit and look blank, relax. Wait and say nothing. People usually need time to think. Practice increasing your wait time. If someone says, "I don't understand," read the question again, or rephrase it for clarification, but be careful not to change the focus. As Mary Budd Rowe says, "Inquisition is something teachers do to students. Inquiry is something teachers and students may do together." Allow time to think.

SUMMARY

The teacher must play many different roles in the classroom. One of the most important of these roles is that of discussion facilitator. In this role, the teacher must understand and practice skills characteristic of good leadership in order to establish and maintain group involvement and interaction. As facilitator the teacher role requires different kinds of discussion techniques and requires the teacher to act in different ways. Knowing how and when to use the skills characteristic of these roles allows the teacher to most effectively help students to learn.

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